NATIONAL DISASTER
MANAGEMENT AUTHORITY

INFRASTRUCTURE AUDIT GUIDELINES

FOR DISASTER RESILIENCE

2025

Infrastructure Advisory &
Project Development Wing

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Chapter3: Recommended Strengthening and Retrofitting Techniques for Buildings Against Flooding and Earthquake Hazard

Message from Chairman

Pakistan, located in a region prone to the natural hazards such as earthquakes, floods, and other disasters, faces ongoing risks to its infrastructure. As the frequency and severity of these events rise, safeguarding the resilience of our built environment has become an urgent priority. Infrastructure is the backbone of our economy and society and a critical lifeline during crises. Ensuring the structural integrity of our buildings has never been more crucial.

With the rapid growth of cities and towns and the continuous expansion of the infrastructure, it is essential to proactively assess and address vulnerabilities within the structures that serve our communities. This document marks a pioneering effort in Pakistan, providing the first comprehensive set of guidelines to address the growing threat of natural disasters. These guidelines offer a robust framework for conducting detailed audits to assess the vulnerability of existing infrastructure, identify weaknesses and recommend retrofitting and strengthening measures to improve disaster resilience.

This initiative is a significant step toward realizing a more resilient Pakistan. The key goal is not only to prevent infrastructure damage but also to protect lives and ensure the swift recovery of communities' post-disaster. By equipping engineers, architects and local authorities with the tools and knowledge to assess and enhance infrastructure resilience, we are laying the foundation for a safer, more sustainable future.

I commend the tireless efforts of those involved in developing these guidelines and to encourage all stakeholders including federal and provincial governments,private sector and local authorities to proactively implement these recommendations. The collective involvement of all sectors is essential for turning this vision into reality.

Together, we can build a more resilient Pakistan, prepared to face the key challenges of climate change and an increasingly unpredictable world.

Lieutenant General Inam Haider Malik HI (M)
Chairman NDMA

Acknowledgement

The Infrastructure Advisory and Project Development (IA&PD) Wing of the NDMA is pleased to launch the infrastructure audit guidelines for Pakistan based on various disasters. The book guides in assessing the resilience of buildings in the context of Pakistan. For this purpose, a thorough study was conducted on the existing global infrastructure audit mechanisms.

We want to acknowledge the efforts of the Chairman NDMA for his guidance and constant support in formulating and compiling these guideline. The IA&PD wing would like to acknowledge the International Finance Corporation (IFC) for its BRI framework, which served as the base document for formulating the Pakistan-specific Infrastructure Resilience Index.

Furthermore, we would also like to acknowledge Sangeeta Pandey et al. (2023), whose research helped us formulate the detailed visual inspection checklist. In addition, we would also like to acknowledge the Pakistan Engineering Council, FEMA and ASCE, whose standards served as reference documents for this publication. Finally, we would like to acknowledge the guidance of the Executive Director (IA&PD) in compiling this book. His valuable input and guidance enabled the IA&PD wing to formulate specific and detailed guidelines.

Preface

The Infrastructure Advisory and Project Development IA&PD wing of NDMA is pleased to the launch of first-ever infrastructure audit guideline for Pakistan. This guideline focuses on proactively identifying Infrastructure at risk in the pre-disaster phase, which will minimize fiscal loss and fatalities during the Disasters.

There was a lack of clear guidelines for assessing the infrastructure resilience in Pakistan and this publication will help bridge this gap, resulting in the enhancement of structural resilience in the longer run. A detailed audit mechanism has been devised in these guidelines, comprising of two phases, namely, the macro and micro phases. Macro phase is based on visual inspection, a detailed checklist and ground surveys. Based on this field data, a detailed IRI rating system has been devised in line with Pakistan's infrastructure situation, enabling industry practitioners to assess the resilience of a building. In cases where the macro audit does not adequately consider the structural systems, the micro audit comes into play, consisting of non-destructive testing techniques and software analysis. Adopting such a stepwise mechanism will ensure effective implementation and reduce the financial and technical requirements for adopting this mechanism.

The audit techniques and tools have been carefully selected, keeping in view their technical and economic feasibility from the perspective of Pakistan. Furthermore, commonly used software, which are widely operated by industry practitioners have been recommended.

These guidelines identifies the issues and attempt to address the problem through the effective retrofitting and structural improvement techniques. For this purpose, a separate chapter has been incorporated, underlining various effective retrofitting methods that align with the identified structural defects. These techniques have also been selected in line with their economic feasibility and ease of applicability.

In conclusion, these guidelines can be an effective tool for industry practitioners, the disaster management professionals, and policymakers to enhance Pakistan's infrastructure resilience and achieve a safer and more resilient future.

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Chapter 1:

The Role of Infrastructure Audits in Disaster Resilience

1 Introduction

Most economic and life losses during disasters in Pakistan are caused by infrastructure damage such as public, residential, commercial buildings, communication, industrial facilities and hydraulic systems. Many structures in Pakistan are ageing and were not built to modern standards, increasing their susceptibility to damage during disasters. The loss and reconstruction cost of damaged infrastructure is unbearable for such a feeble economy. Given the country's vulnerability to natural disasters such as earthquakes, floods and landslides, ensuring the resilience and safety of construction infrastructure is crucial. Identifying structural weaknesses and potential hazards in buildings and other infrastructure is essential and can prevent catastrophic failures during natural disasters.

Proactive maintenance and retrofitting can significantly reduce the risk to human lives and property, for instance seismic retrofitting can increase a building's resistance to earthquake damage by up to 80%, significantly reducing the potential for catastrophic damage and loss of life during seismic events. Pakistan lacks a formal policy for regular infrastructure audits, leading to unassessed vulnerabilities. There was a need to develop an infrastructure audit policy at the national, provincial and distri ct levels to ensure regular maintenance and retrofitting, compliance with design and construction codes, and better preparedness in the face of disaster. Addressing vulnerabilities through audits and subsequent retrofitting can be more cost-effective than emergency repairs or reconstruction after a disaster, preventive retrofitting costs are approximately 30% of the potential cost of rebuilding, whereas repair costs can be 3 to 8 times higher than retrofitting. Regular infrastructure audits help in mitigating risks and enhancing overall safety. In addition to that, frequent audits and maintenance improve the longevity and functionality of infrastructure, making it more sustainable over time. Resilient infrastructure is crucial for minimizing damage and facilitating quick recovery in regions prone to natural disasters. Preparedness through infrastructure audits ensures that communities can withstand and rapidly recover from disasters.

2 Objectives

The key objectives of these guidelines are as follows: -

- Pinpoint areas and structures that are susceptible to damage from natural disasters
- Ensure structural safety under normal and extreme conditions
- Early detection of damage to prevent catastrophic failures
- Support decision-making for disaster preparedness and recovery
- Monitor post-disaster structural integrity for safe reuse
- Empowerment of relevant departments to carry out audits and retrofitting measures
- Proactively mitigate impacts of disasters on existing and under-construction infrastructure
- Suggesting and enforcing necessary upgrades, maintenance and retrofitting measures to enhance resilience

3 Role of Infrastructure Audit in Enhancing Disaster Resilience

An infrastructure audit is a cornerstone in enhancing disaster resilience, as it systematically evaluates the strengths and weaknesses of critical infrastructures. An audit ensures that potential failure points are addressed before disaster strikes by identifying vulnerabilities in structures such as buildings, bridges, water supply systems and power grids, etc. For example, audits can reveal design, materials or maintenance inadequacies that could compromise structural integrity during earthquakes, floods or any other disaster. This proactive approach reduces the likelihood of catastrophic damage and loss of life.

Moreover, an infrastructure audit assesses the degree of hazard exposure infrastructures face. It considers factors such as geographic location, environmental conditions and historical disaster data to determine the risks from natural events. With this information, planners can prioritize retrofitting and upgrading critical structures in high-risk areas. By integrating the findings of an audit into urban planning and development policies, communities can enhance their overall resilience to disasters.

The audit also strengthens operational preparedness by evaluating the infrastructure's redundancy and recovery capacity. For instance, it examines whether backup power systems, water supplies or communication networks are available and sufficient to function during and after a disaster. Identifying interdependencies between systems, such as hospitals' reliance on uninterrupted power, enables more comprehensive disaster response and recovery planning. This ensures that essential services remain operational, mitigating the secondary impacts of disasters on affected populations.

Finally, infrastructure audits foster informed decision-making and investment in disaster resilience. The detailed data generated through audits allow stakeholders scuh as government agencies, engineers and local communities to prioritize interventions based on urgency and impact. Audit recommendations often drive the adoption of innovative technologies, resilient construction practices and nature-based solutions such as green infrastructure for flood management. This way, audits reduce disaster risks and promote sustainable and adaptive development.

4 Infrastructure Audit in the Context of Pakistan

The loss and reconstruction cost of damaged infrastructure is unbearable for such a feeble economy. Given the country's vulnerability to natural disasters such as earthquakes, floods and landslides, ensuring the resilience and safety of construction infrastructure is crucial. Identifying structural weaknesses and potential hazards in buildings and other infrastructure is essential and can prevent catastrophic failures during natural disasters.

Proactive maintenance and retrofitting can significantly reduce the risk to human lives and property. Pakistan lacks a formal policy for regular infrastructure audits, leading to unassessed vulnerabilities. There was a need to develop an infrastructure audit policy at the national, provincial and district levels that can ensure regular maintenance and retrofitting, compliance with design and construction codes and better preparedness in the face of disaster. Addressing vulnerabilities through audits and subsequent retrofitting can be more cost-effective than emergency repairs or reconstruction after a disaster.

Regular audits of infrastructure play a vital role in reducing risks and boosting overall safety. Conducting frequent inspections and maintenance enhances the durability and performance of infrastructure, contributing to its long-term sustainability. Building resilient infrastructure is essential for limiting damages and supporting swift recovery, especially in areas vulnerable to natural disasters. Proactive preparedness through infrastructure assessments ensures that communities are better equipped to endure and quickly bounce back from such events.

Chapter 2:
Techniques of Infrastructure Audit

1 Visual inspection

Figure 1: Visual Inspection of Building

Visual inspection is done by employing experience gained by the engineer and various research articles published in the field of structural auditing of a building, as illustrated in **Fig. 1**. The visual inspection process starts with the assessment of cracks, dampness, spalling over the surface of any walls, columns, slab and all other structural and non-structural components of the building. It includes quantifying the moisture over the walls and other members.

The following factors are considered while visually assessing a structure for structural and non-structural deficiencies:

a. Design Changes

Auditing a building involves reviewing the current structural and architectural design against the original approved plans. This helps identify any unauthorized changes, such as modified layouts, additional structures or removed elements, that could affect the building's safety and stability. It is essential to refer to the original design documents and closely examine areas where changes have been made to ensure they comply with safety standards and building codes.

b. Structural Defects

Auditing for structural defects involves examining all load-bearing components, such as beams, columns and slabs, for signs of damage or weakening. This includes looking for misalignments, sagging, uneven surfaces, or deformations that may indicate potential structural failure. The procedure also involves inspecting connections, joints and reinforcement to ensure they are intact and functioning as intended. Detailed documentation of observed defects and their possible causes and severity is critical for recommending appropriate repair or reinforcement measures.

Figure 2: Structural Defects in Building - Shifting Column Centers

c. Material Deterioration

Visual inspection also helps in assessing the condition of construction materials, such as concrete, steel, brick or timber, for signs of ageing, wear or chemical damage. This includes identifying corrosion, efflorescence, scaling or discoloration. Non-destructive tests, such as rebound hammer tests for concrete or ultrasonic testing for steel, can be employed to assess material strength. Environmental factors such as moisture, temperature fluctuations and exposure to chemicals should also be considered, as they may contribute to material degradation.

Figure 3: Deterioration of Old Age Building

d. Cracks

Figure 4: Cracking in a Wall

Auditing for cracking involves a detailed examination of all structural and non-structural elements, with attention to the cracks' size, pattern and location. These cracks are categorized based on their type, such as shrinkage, settlement or structural cracks, which may indicate significant underlying issues. Tools such as crack width gauges are utilized for precise measurement. It is essential to determine whether cracks are active (progressive) or dormant and to analyze their potential impact on the structural integrity and serviceability of the building.

e. Damping and Leakages

Auditing for dampness and leakages involves comprehensively inspecting areas susceptible to water ingress, such as roofs, walls and basements. Indicators of dampness include discoloration, peeling paint, mold growth or softening of plaster. Moisture meters can assess the extent of dampness, while infrared cameras may detect hidden water leaks. Identifying the source of leakage, such as faulty plumbing, cracks or inadequate drainage systems and evaluating the effectiveness of existing waterproofing measures is crucial.

Figure 5: Dampness on the Walls and Roof of Building

f. Non-Destructive Testing

Non-destructive Testing detects quality without destructing the material or changing its properties. Estimating concrete strength, evaluating existing conditions and placement of rebars are crucial aspects of construction, as well as providing insights into the material's durability and structural integrity.

Figure 6: Non-Destructive Testing Methods

2 Audit Mechanism

The audit mechanism is divided into two sections: **Macro audit** and **Micro audit**. The macro audit is carried out through an on-ground assessment using a visual inspection sheet, **Infrastructure Resilience Index** rating scale and resilience

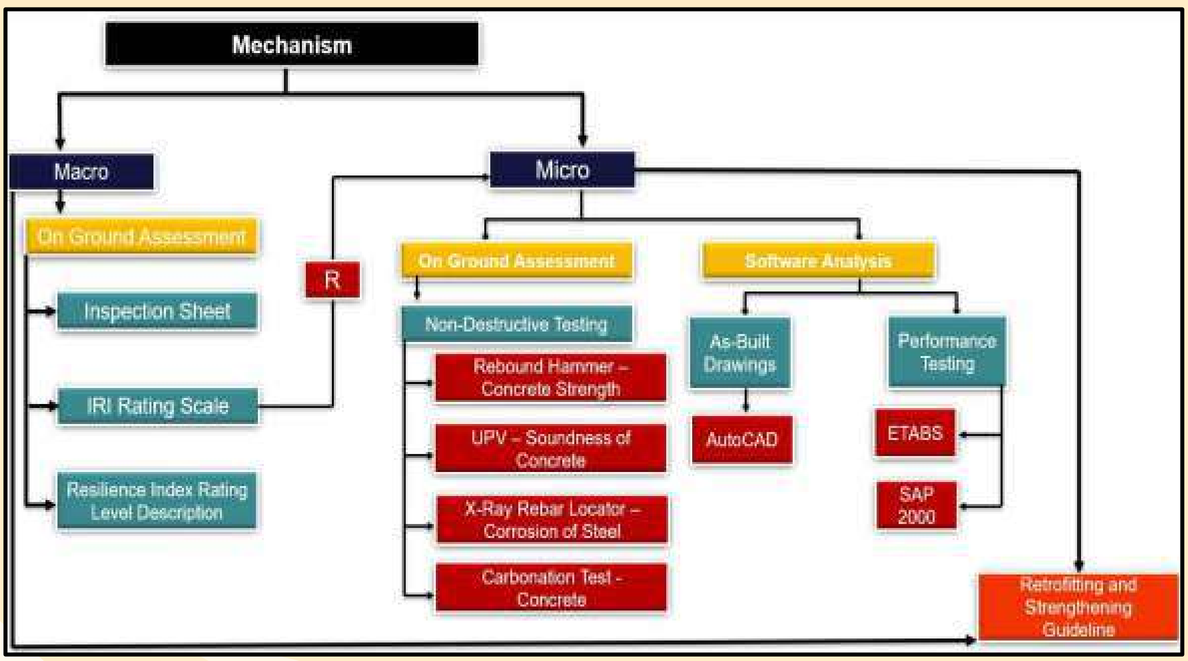

Figure 7: Flowchart Depicting Audit Mechanism

index rating level description. Furthermore, if the resilience of a structure is less than 50%, a micro audit is carried out through non-destructive testing and software analysis. Post assessment, suitable retrofitting and strengthening measures are identified and implemented to enhance overall structural resilience against various disasters.

3 Macro Audit

a. Checklist/Visual Inspection

Visual inspection of deteriorating reinforced concrete structures is an integral aspect of routine assessment practices. Data collected through visual inspection is primarily qualitative and subjective. This guide provides structural inspectors and facility engineers with the methodology for visually and systematically inspecting any civil structure. With the help of basic technical and geographical design information, inspectors can add value to evaluating the deteriorated condition of structures. It primarily assesses houses and public, private and commercial buildings. The categories in which structures to be categorized are: Firstly, structure is entirely safe and satisfies all safety and serviceability requirements. Secondly, the structure has structural damages or is deficient, which can be rectified by retrofitting, rehabilitation, etc., to satisfy the performance set by the user. Lastly, the structure is badly damaged and no further repair is economical or safe; hence, it must be demolished and rebuilt later.

b. Why perform a Visual Inspection with a Checklist?

Visual Inspection is the first step towards the performance of Structural Health Assessment (SHA) and all further decisions regarding modelling, non-destructive or destructive testing, repair, retrofitting, rehabilitation, demolition, etc., lie on the visual inspection results. A systematic approach must be adopted for visual inspection that would allow stepwise coverage of all the essential factors without missing any component or element of the structure.

c. Considerations for Checklist Development

The checklist was developed to focus on all considerations required to analyze a structure visually. Factors such as seismic zone, wind zone, flood zone, cyclone, tsunami, landslides, type of structure, design and drawing details and type of damages (architectural and structural) were considered during checklist development. The checklist was prepared systematically, incorporating all general information, including the exterior envelope and the component inspection. The defects such as abrasion, blistering, chemical deterioration, cracking, crazing, discoloration, dampness, disintegration, distortion, efflorescence, honey-combing, pop-outs, peeling, spalling, differential settlements, shrinkage, stratification, carbonation, corrosion, ASR (alkali-silica reaction), AAR (alkali-aggregate reaction), termite effects and others are to be considered for all places of frequent occurrences like exterior and interior walls, openings, foundations, columns, beams, slabs etc. Cracking patterns (plastic/active/passive/longitudinal/transverse/diagonal/single, etc.) are to be mentioned to assess the severity of damages. The severity of cracking is considered a function of crack width (Hairline: up to 0.1mm; Minor: 0.1mm to 0.3mm; Moderate: 0.3mm to 0.6mm; and Severe: Greater than 0.6mm). Colour considerations such as yellow, orange or red can be integrated to ensure safety, damage and repairability or severely damaged. A marking system may be developed to complete the assessment by summing up marks given to each section (5-no repair, 4-aesthetic repair, 3-minor structural repair, 2-major architectural/structural repair needed, 1-overall repair, 0-beyond repair). If any part has been opened for examination (veneer/ lamination /false ceilings), it should be mentioned on the checklist.

Table 1: Checklist for Non – Rating points for Macro Audit of Structures

Visual Inspection Checklist		
Sr. No.	**Description**	**Details**
1	Structure Name	
2	Date of Inspection	
3	Nature/Usage of Structure	
4	Type of Structure: Adobe, Brick, Block, Stone, Timber	
Building Information		
5	Seismic Zone	
6	Wind Zone	
7	Snow Fall Zone	
8	Tsunami Zone	
9	Flood Zone	
10	Use/Purpose	
11	Damages in Past	
12	Previous Repair/ Alterations/ Retrofitting	
Details as per Drawings and Records		
13	Plan/Elevation/Structural Drawings	
14	Number of Storeys	
15	Per Floor Area Detail	
16	Plan and Elevation Symmetrical or Not	
General Details		
17	Availability of Drawings	
Soil/Foundation Details		
18	Type of Foundation	
19	Any Active Water Body Near the Structure	
Exterior Envelope Inspection		
Wall/Parapets		
20	Type of Wall (Rcc Framed/Load Bearing/Semi Load Bearing/Other)	
21	Role of Wall (Masonry Infill/Load Carrying)	
22	Lintel Bands Present or Not	
Foundation		
23	Method Used to Access Condition of Foundation	
Floor, Ceilings and Partitions		
24	Type of Flooring	
Component Inspection		
Walls (Interior)		
25	Role of Wall (Structural Support / Masonry Infill	

Table 2: Checklist for Rating points for Macro Audit of Structures

Visual Inspection Checklist			
Sr. No.	Description	Rating	Other Details
Soil/Foundation Details			
1	Any Signs of Erosion of Soil		
2	Signs of Disturbed Soil due to Animal Burrow		
3	Is Soil being Retained by Structure?		
4	Evidence of Settlement Around the Perimeter of Building		
5	Wall Conditions with Dampness/Seepage/Out of Alignment/Leaning In or Out		
6	Cracks (Pattern and Nature)		
7	Vegetation/Tree Root Damage to Structure		
Drainage			
8	Infiltration Condition in Building		
9	Algae/Fungi on the Surface of the Building		
10	Drainage Capacity		
11	Flash Joints, Weep Holes, etc.		
Chemical Effects			
12	Chemical Corrosion		
Exterior Envelope Inspection			
Wall/Parapets			
13	Building Material Used		
14	Deflection, Cracks (Type, Width, Depth and Crack)		
15	Any Surface Defects		
16	Damages to Parapets and Chajjas		
17	Signs of Water Filtration Around Openings and Other Parts		
18	Cracks in the Joining of Masonry		
Opening Details			
19	Deflection and Sagging of Wall Above or Below the Openings		
20	Diagonal Cracks at the Corner of Openings		
21	Distortion of Openings		
22	Water Infiltration symptoms		
23	Evidence of Abrasion and Impact		
24	Evidence of Termite Effects on Doors and Windows		
25	Condition of Material Used for Doors, Windows, etc.		
Roof			
26	Water Proofing		
27	Water Stagnancy		
28	Condition of Roof Slopes, Rain Water Pipe, Clogging, etc.		
29	Sagging of Roof		
30	Water Infiltration at Openings or Joints, etc.		

31	Structural Defects on the Roof Surface		
Foundation			
32	Cracks in the Foundation		
33	Location of Cracks		
34	Differential Settlement of Foundation		
Floor, Ceilings and Partitions			
35	Differential Settlement on Floor		
36	Cracks on Floor		
37	Sagging/Bulging/Discoloring		
38	Condition of Flooring		
39	Partition Material and Condition Detail		
40	Ceiling Material and Condition Detail		
Component Inspection			
Walls (Interior)			
41	Sign of Water Penetration		
42	Role of Wall (Structural Support/Masonry Infill)		
43	Plumb detail of Wall		
44	Surface Defects of Wall		
Columns			
45	Proper Alignment of Columns		
46	Plumb of Column		
47	Cracks (In Column) Patterns of Cracks Width/Depth of Cracks		
Beam & Girders			
48	Deflection		
49	Cracking		
50	Change in Section Sizes		
51	Corrosion Condition		
52	Condition of Lateral Support of Framing Structures		
53	Evidence of Abrasion		
54	Abrasion due to Sliding or Cracks Due to Stress Concentration		
55	Location of Cracks/Deflection (Location)		
Intersections/Connections			
56	Cracks/Deflection at the Intersection of Beams and Columns, Beams and Slabs, Columns and Foundations		
57	Steel/Other Connection Conditions		
58	Surface Defects at Connections or Intersecting Areas		
59	Corrosion Severity of Steel-to-Steel Connections		
Slabs			
60	Cracking at Column Base		
61	Sign of Settlements		
62	Floor/Wall Settlements/Separations or Settlements		
63	Condition of Water Proofing		

64	Circumferential Cracking		
Flooring			
65	Cracking		
66	Sign of Settlements		
67	Floor/Wall Settlements/Separations or Settlements		
68	Circumferential Cracking		
Staircase			
69	Damages on Stairs		
70	Cracking/Corrosion		
71	Exposure of Reinforcement (if any)		
72	Condition of Hand Rails, Rise, Treads, Landing, Platform, etc.		
73	Condition of Connection/Anchorage of Hand Rails		
Lift			
74	Condition of Chord, Grills, Doors, Buttons, Switches, Fan, Lights, etc.		
Sanitary Fittings & Plumbing			
75	Severity of Leakages/Seepages Due to Pipes/Fittings Etc.		
76	Condition of All the Pipes with Fittings and Accessories		

Significant Findings (with location details)

Further Recommendations ________________________________

Repairs Required ______________________________________

Signature of Inspector

Signature of Owner

Date: ________________

Place: _______________

d. Points Rating Mechanism

The checklist comprises 101 total points to assess the building and hazard conditions surrounding the building. The checklist consists of 25 non-rateable points in Table 1 and 76 rateable points, rated from 1 to 5 based on the condition and severity. The maximum score a building can achieve is 380, which implies that the building is 100% resilient to the mentioned hazard. It is understood that even the highest levels are not 100% resilient, but they retain certain residual risks. The score achieved by a building is divided by the total score, which is then multiplied by 100 and converted into a percentage. The percentage represents the resilience of the building and the remaining percentage represents the category in which it falls in IRI based on Resilience and Maximum Probable Loss.

e. Infrastructure Resilience Index

The Infrastructure Resilience Index (IRI) is a standardized measure designed to assess and enhance the resilience of buildings against potential hazards. It facilitates access to location-specific natural hazard information, provides resilience measures to mitigate applicable risks and improves transparency when disclosing a building's resilience information among concerned stakeholders. Infrastructure resilience makes it easy for stakeholders, including construction developers, financial institutions, insurers, and governments, to assess, improve and analyze the strength of buildings. The IRI provides a relative rating of resilience from higher to lower and reduce structural risk of buildings rather than an absolute rating against some performance standard.

f. Assessment Scope

All types of buildings can use the Infrastructure Resilience Index: residential, commercial, institutional, and public. These can be new buildings in planning or design, buildings that may be renovated or existing buildings.

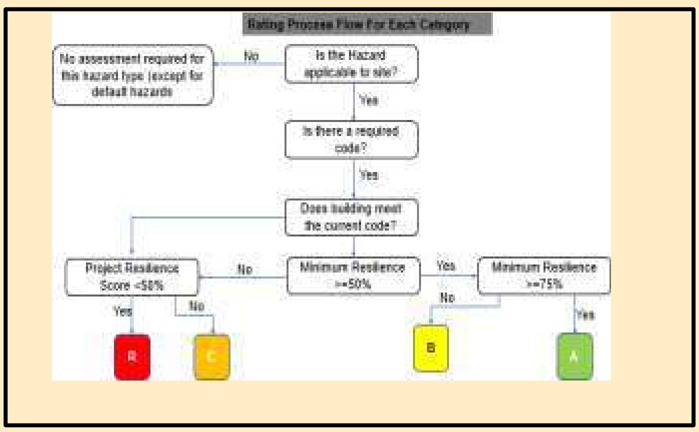

Figure 8: IRI Rating Process Flow Chart

g. IRI Rating Process Flow Chart

i. IRI Rating Scale

The IRI has adopted the World Bank's 5-level rating scale, as depicted in **Fig. 9**. These levels are also described in the Table 3 shown below and explained in the following sections. The categories show Probable Maximum Loss (PML), which the different category of buildings can face during a disaster.

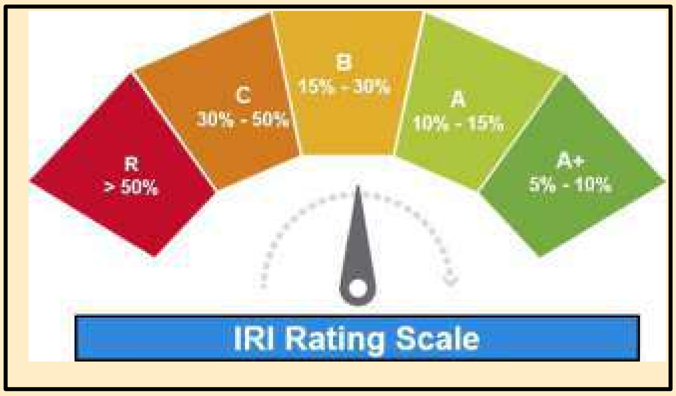

Figure 9: IRI Rating Scale

ii. Infrastructure Resilience Index

Based on Probable Max Loss that can occur, the structures are divided into 5 categories as shown in Table 3. If the score from the checklist is below 190, the building will fall in category R, meaning the structure has a probable maximum loss capacity of greater than 50% and resilience less than 50%. This would require an in-depth understanding and assessment to recommend tailored retrofitting and strengthening.

Table 3: Categories for Infrastructure Resilience Index

Level	Probable Max Loss	Definition
A+	5% - 10%	'A' with operational continuity measures
A	10% - 15%	The building incorporates global best practice mitigation measures for all applicable hazards. Which are generally set above the local building code. It will likely survive all hazards at high level.
B	15% - 30%	The building incorporates local building code requirements for all applicable hazards and many recommended good practices. It will likely survive some applicable hazards at a moderate-high level.
C	30% - 50%	The building incorporates local building code requirements, some of which may be outdated, and some recommended practices. It may survive some applicable hazards at a moderate level.
R	>50%	The building fails to meet the requirements of any of the above levels. It will likely not survive most applicable hazards, even at moderate levels

3 Micro Audit

a. Non-Destructive Testing

Non-destructive testing (NDT) is a critical method for assessing the structural health of buildings, bridges and other infrastructure without causing any damage to the materials. Using various techniques, such as ultrasonic testing, radiographic testing and acoustic emission testing, NDT allows for detecting internal flaws, cracks, corrosion or other forms of deterioration. These methods can identify potential weaknesses early on, helping to prevent costly repairs or catastrophic failures. NDT is particularly valuable in ensuring the safety and longevity of structures, as it provides accurate data on material properties and stress conditions without interrupting everyday use. Additionally, it enables regular inspections to be conducted without extensive dismantling or invasive procedures. As a result, non-destructive testing is an essential tool in civil engineering, providing vital insights that help maintain the integrity of critical infrastructure and ensure public safety.

i. Rebound Hammer Test

Figure 10: Non-Destructive Testing & Evaluation of the Requirements of Construction Standards

Schmidt's Hammer Test is based on the principle that the "rebound of a spring-loaded mass depends on the hardness of the concrete surface on whic the hammer strikes." This rebound distance of the rebounded plunger mass is noted in the graduated scale as the rebound number/rebound index. The graph in the hammer's body is used to determine the respective compressive strength. The concrete with low energy and stiffness absorbs more energy from the plunger, producing a low rebound value on the scale. This is crucial in calculating the strength of concrete or brick.

The Objective of the Rebound Hammer Test

1. To assess the compressive strength of concrete
2. To compare the quality of two different concrete pour
3. To determine the quality of concrete against the requirements of construction standards
4. To detect the locations of weak concrete slabs of concrete with voids

Figure 11: Apparatus of Schmidt Hammer

Procedure:

It involves the NDT inspector and NDT technician preparing the concrete surface, calibrating the hammer, selecting test locations, holding the hammer, striking the surface, taking multiple readings, recording, correlating and interpreting results.

The process involves ensuring the surface is clean and free from loose particles or debris by NDT Professionals. Once calibrated, the rebound hammer is positioned perpendicular to the surface of the concrete structure to capture readings. The test can be performed horizontally on a vertical surface or vertically upwards or downwards on horizontal surfaces.

The rebound hammer is then placed against the concrete surface, releasing the hammer to measure the rebounded energy. Factors such as NDT Techniques for surface flaws, moisture content and reinforcing bars should be considered when interpreting the results.

ii. Ultrasonic Pulse Velocity

Ultrasonic Pulse Velocity (UPV) testing is a non-destructive technique widely employed in Civil Engineering to assess the integrity and quality of concrete structures. This method utilizes ultrasonic pulses to measure the speed of sound waves as they travel through a concrete specimen, providing valuable information about the material's uniformity, homogeneity and potential presence of defects such as cracks in concrete. UPV testing is crucial for evaluating the concrete quality and homogeneity, detecting poor patches, internal flaws, cracks and honeycombing. Its non-invasive nature and ability to provide quick and reliable results make it an essential component of concrete quality control.

Figure 12: Apparatus of Ultrasonic Pulse Velocity Test

Figure 13: Ultrasonic Pulse Velocity Test on Beams and Slabs

Ultrasonic Pulse Velocity Test vs Quality of Concrete

The guidelines provided below have been developed to characterize the quality of concrete in structures based on ultrasonic pulse velocity. These guidelines enable the assessment of concrete quality in terms of uniformity, the presence or absence of internal flaws, cracks, segregation and other factors that indicate the level of workmanship employed.

Table 4: Classification of the Quality of Concrete on the Basis of Pulse Velocity

Sr. No	Pulse Velocity (Km/sec)	Quality of Concrete
1.	> 4.5	Excellent
2.	3.5-4.5	Good
3.	3-3.5	Medium
4.	< 3	Doubtful

Application for Ultrasonic Pulse Velocity test

The applications of the Ultrasonic Pulse Velocity test are:

- Evaluates concrete quality and homogeneity
- Detects poor patches, internal flaws, cracks and honeycomb
- Predicts concrete strength
- Assesses dynamic Young's Modulus
- Estimates depth of cracks in concrete

iii. X-Ray Rebar Locator (Profometer Test)

The profometer test is a non-destructive testing technique used to detect the location and size of reinforcements and concrete cover quickly and accurately. A small, portable and handy instrument known as a profometer or rebar locator is used in this test. The equipment weighs less than two kg, works on standard batteries and thus does not require any electrical connection. The basic principle in this test method is that the presence of steel affects the electromagnetic field, which is directed by a profometer device.

This instrument has sufficient memory to store measured data. Integrated software is loaded into the equipment for complicated calculations and printing statistical values.

The profometer test is widely used and has many applications. For instance, it is used to specify reinforcement size, location and condition of existing structures to evaluate their actual strength and location reinforcement is necessary to be determined before drilling and cutting cores for testing concrete, analysis of corrosion, conformity check and quality assurance.

Figure 14: Profometer Test for Rebar Assessment and Corrosion Analysis

Purpose of Profometer Test

- Assess the location of steel bars
- Measure the diameter of reinforcement bars
- Evaluate the thickness of the concrete cover

Profometer Test Procedures

Determine Steel Bar Location

Path measuring devices and spot probes are used together for path measurements and scanning of rebars. These are connected to the profometer via cables and moved on the concrete surface to scan the rebars and measure the spacing. The bar is displayed on the screen as soon as it is located. Once the bar is located, it is marked on the concrete surface.

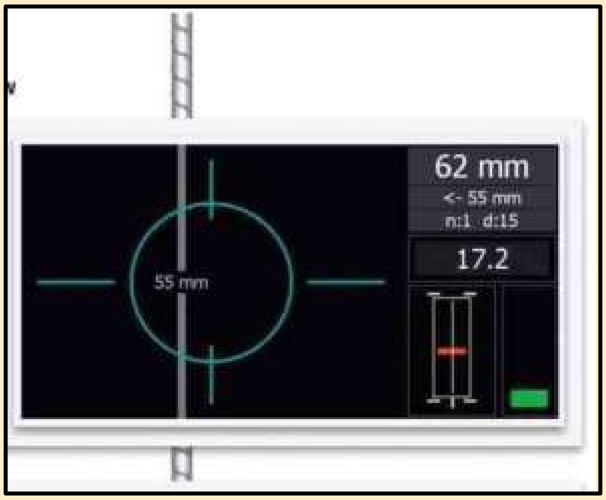

Figure 15: Detection of Rebar Location

Measure Bar Diameter

A diameter probe is used to measure the diameter of the bars. It is also connected to a profometer by a cable. After finding out the location of the rebar, the diameter probe is placed on the bar parallel to the bar axis. Four readings are displayed and the mean value of these readings is taken as the diameter of the bar.

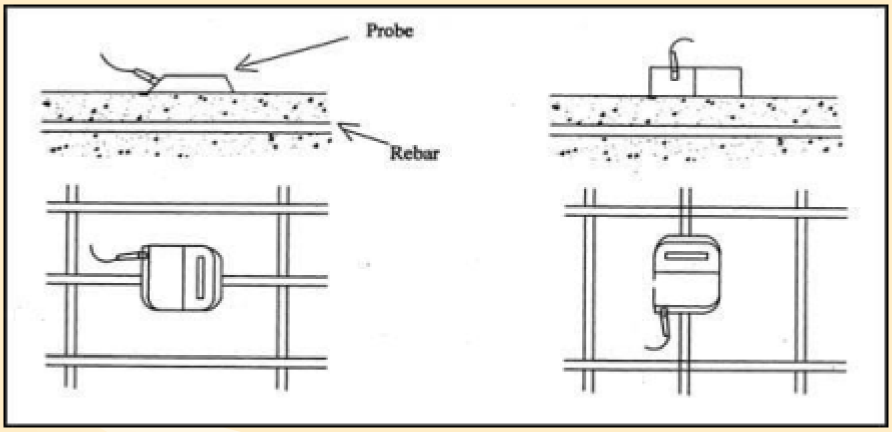

Figure 16: Diameter of Rebar

Determine Concrete Cover

A depth probe of the profometer is used to measure the cover. It is also connected to a profometer by cable and is placed precisely on the bar. As soon as the depth probe is above the rebar or nearest to it, it gives an audio signal through a short beep and visual display. Simultaneously, the measured concrete cover is stored in memory.

iv. Carbonation Test

Carbon dioxide (CO_2) from the air reacts with the calcium hydroxide ($Ca(OH)_2$) in concrete to form calcium carbonate ($CaCO_3$), reducing the concrete's alkalinity and increasing the risk of reinforcement corrosion. Carbonation of concrete is a slow and continuous process progressing from the outer surface inward but slows down with increasing diffusion depth.

Cement paste contains 25-50 wt.% calcium hydroxide ($Ca(OH)_2$), which means that the pH of the fresh cement paste is at least 12.5. The pH of a fully carbonated paste is about 7. According to Eq 1, the concrete will carbonate if CO_2 from the air or water enters the concrete:

$$Ca(OH)_2 + CO_2 \longrightarrow CaCO_3 + H_2O \qquad \textbf{(1)}$$

When $Ca(OH)_2$ is removed from the paste, hydrated calcium silicate hydrate (CSH) will liberate Calcium Oxide (CaO) and carbonate. The carbonation rate depends on the porosity and moisture content of the concrete. The carbonation process requires water because CO_2 dissolves in water, forming Carbonic Acid (H_2CO_3). If the concrete is too dry (RH <40%), CO_2 cannot dissolve and no carbonation occurs. If, on the other hand, it is too wet (RH >90%), CO_2 cannot enter the concrete, and the concrete will not carbonate. Optimal conditions for carbonation occur at an RH of 50% (range 40-90%).

Carbonation has three effects: it increases the mechanical strength of the carbonated concrete, reduces permeability, and decreases alkalinity, which is essential for the corrosion prevention of reinforcement steel. Reinforcement in concrete will not corrode if the pH of the concrete is maintained at around 13. Carbonation reduces the pH level of concrete. Below a pH of 10-11, the steel's thin surface passivation layer dissolves, and corrosion is promoted. The pH of carbonated concrete drops to about 7; thus, carbonation provides a favorable condition for corrosion. The depth of carbonation increases with an increase in water/cement ratio. It is to be noted that reinforcement corrosion will start if the entire cover of the steel is carbonated, but the presence of moisture and oxygen is essential.

The carbonation rate is usually high in dry weather, but the possibility of corrosion is lower due to less moisture content.

One benefit of the carbonation test is that the results are immediate. Removing the sample and shipping it to a laboratory is unnecessary. All testing can be done in the field. Also, the revealer (phenolphthalein) is environmentally safe. Moreover, the test can be performed by anyone. There is no need for special training. However, determining where tests should be taken should be discussed and planned.

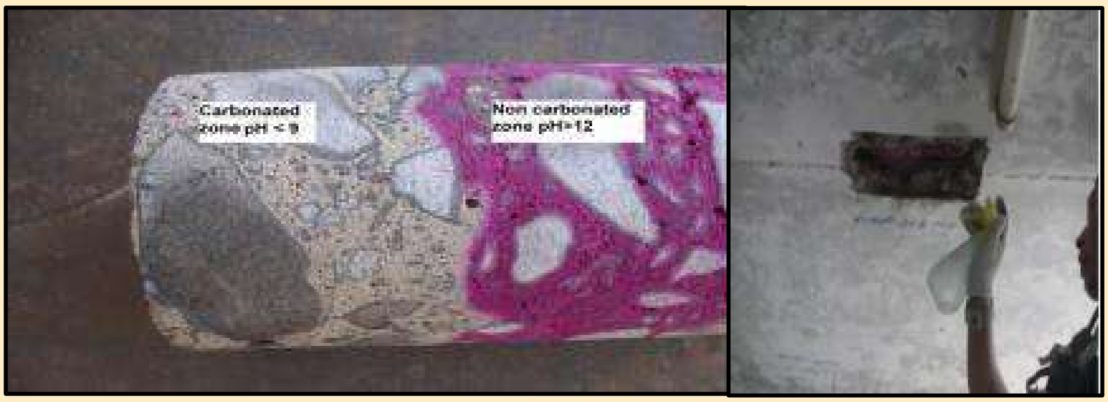

Figure 17: Carbonation Test on Concrete

Material Required

- Phenolphthalein indicator – Dissolve 1g of phenolphthalein into 50 ml of alcohol and then dilute with water to 100 ml.
- Other indicators are thymolphthalein and alizarin yellow.

Application

- Assess the durability of concrete by comparing carbonation depth with concrete cover.
- Determining the cause of corrosion activity.
- Design an effective repair solution.

b. Software Analysis

i. As-Built Drawing – Architectural & Structural

As-built drawings serve as a critical reference during a building audit, providing detailed information about the architectural and structural layout of the structure. These drawings illustrate the actual dimensions, materials and design features implemented during construction, which may differ from the original plans due to modifications or adjustments. These drawings are reviewed to identify any discrepancies, ensure compliance with design specifications, and serve as input for structural analysis. Accurate as-built documentation is essential for understanding the building's current state and assessing its performance.

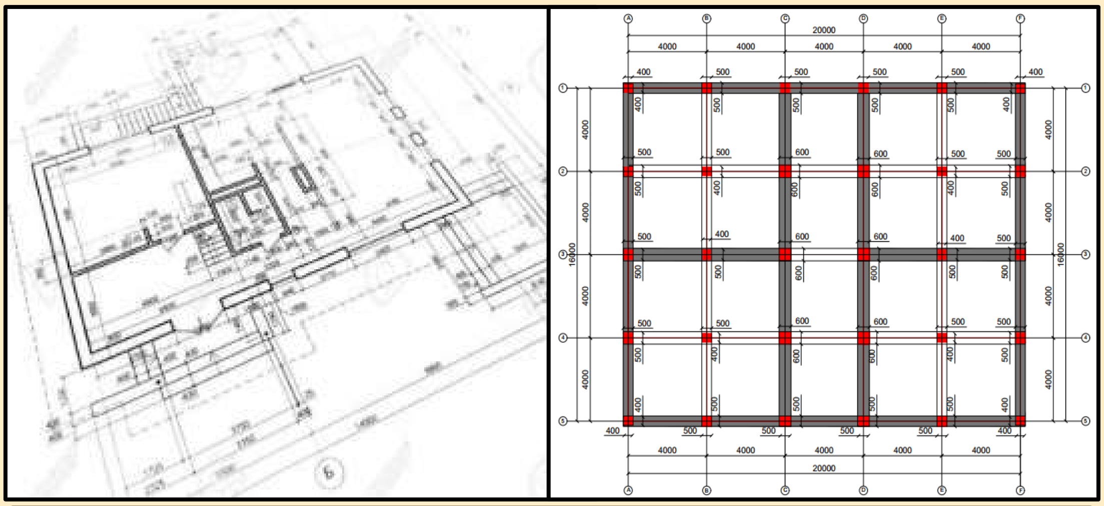

Figure 18: Architectural and Structural Drawings of Structures

c. Software's

i. ETABS

ETABS (Extended Three-Dimensional Analysis of Building Systems) is a specialized software used for building structural analysis and design. It helps simulate the structural behavior of the building under various loads, such as dead

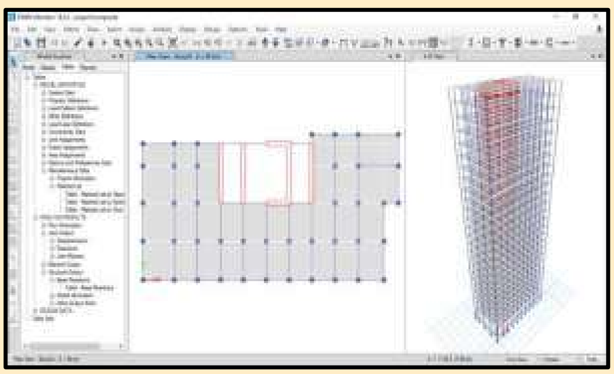

Figure 19: Modelling, Analysis & Design of Buildings Using ETABS

loads, live loads and seismic forces. The software allows detailed structure modelling, including geometry, materials and connections. Results from ETABS provide insights into the adequacy of the structural components, identify weak zones and support re commendations for retrofitting or strengthening measures.

ii. SAP 2000

SAP 2000 is a versatile structural analysis and design software widely used for assessing the integrity of structures. A building audit evaluates the structure's response to different loading conditions, including static and dynamic loads. The software facilitates the modelling of complex structures and assessing stress distribution, deformation and stability. The results of the analysis are crucial for determining whether the building meets current safety standards and proposing necessary corrective actions.

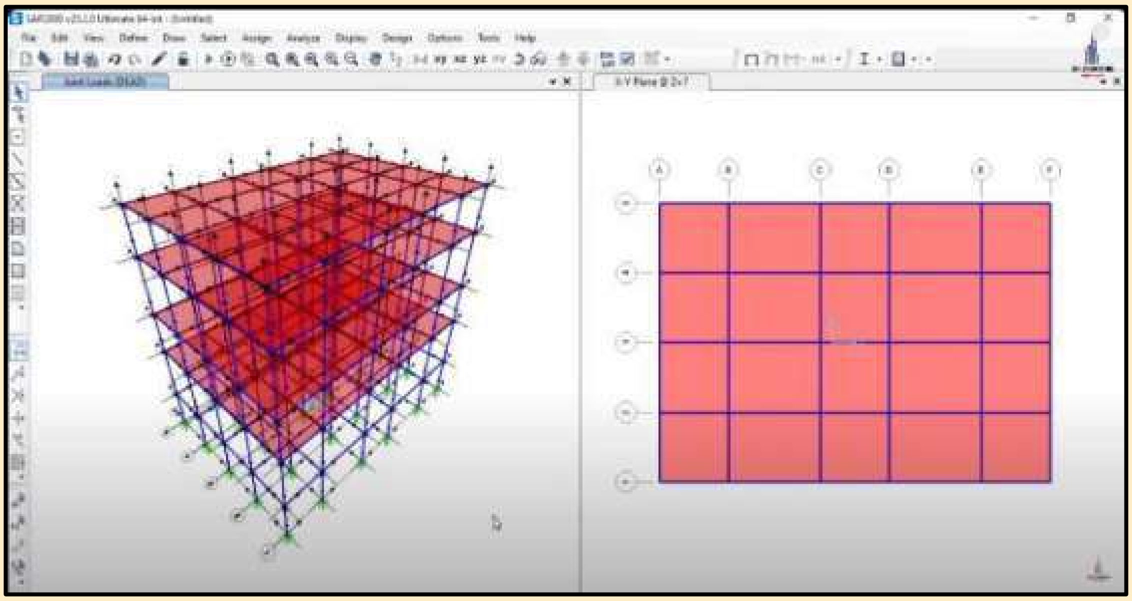

Figure 20: Design of RCC Building using SAP 2000

Chapter 3:

Recommended Strengthening and Retrofitting Techniques for Buildings Against Flooding and Earthquake Hazard

Retrofitting is strengthening existing structures to resist damage from natural and man-made hazards such as earthquakes and floods. This guide provides a detailed overview of retrofitting techniques tailored for housing units, including the specifications for effective implementation. References to standards and guidelines have been provided for credibility.

1 Retrofitting Against Earthquake Hazard

a. Shear Wall Installation

Description: Shear walls are vertical elements that provide lateral stiffness to resist seismic forces. Adding shear walls is an effective method to enhance the lateral load resistance of an existing building during an earthquake. Shear walls help transfer horizontal forces from seismic activity into the foundation, thus preventing structural failure.

Specifications:

- Use high-grade steel reinforcement (Grade-60).
- Reinforced Concrete (RC): The most common material for shear walls due to its high strength and ductility under seismic loading. Use reinforced concrete with a minimum compressive strength of 25 MPa (3,625 psi).
- Steel Reinforcement: Use rebars that comply with standards like ASTM A615 (Grade 60 or higher) and provide adequate vertical and horizontal reinforcement per the design requirements.
- Minimum wall thickness: 150 mm for reinforced concrete shear walls.
- The height-to-thickness ratio of shear walls should typically be between 10 and 20 to ensure efficient seismic performance.
- Placement should align with the building's center of gravity
- Adhere to ACI 318-19 design standards.
- Minimize the number of openings in shear walls to maintain structural integrity. If openings are necessary, ensure that lintels or reinforced

concrete beams are provided above the openings to prevent weaknesses in the wall.

Shear walls must be anchored to the existing foundation to prevent sliding or overturning. This can be achieved by embedding steel dowels or shear bolts into the foundation and floor slabs.

Applications: Recommended for houses and buildings in high seismic zones.

Figure 21: Shear Walls in Buildings

b. Seismic Bracing

Description: Diagonal or cross bracing is added to walls and ceilings to stabilize structural components. Seismic bracing, either through steel braces or timber braces, is a vital retrofit technique to improve the lateral load resistance of existing buildings during earthquakes. Bracing systems help prevent structural failure by transferring earthquake-induced forces to the foundation.

Specifications:

i. Steel Braces:

- Use mild or high-strength steel (Grade 50 or higher) with a yield strength of 345 MPa (50 ksi) or more, depending on the load requirements.
- Typically, steel braces range from 25 mm to 100 mm (1 to 4 inches) in diameter for round members or the equivalent size in structural steel sections (e.g., C-channels, I-beams).
- Maximum slenderness ratio should be 200.

Use high-strength bolts (Grade 8.8 or Grade 10.9) or welded connections to anchor the braces to the building's structural frame. Ensure that connections are designed to resist tension and compression forces. Bolted & welded connections must follow ASTM specifications.

Figure 22: Seismic Bracing in Structures

ii. Timber Braces:

- The timber braces should have a minimum cross-sectional size of 100 mm x 150 mm (4" x 6").
- Use steel connectors such as lag bolts, timber screws or bolts to secure timber braces to the building's frame Ensure the fasteners are capable of transferring shear and axial loads effectively.
- Timber braces are typically configured as diagonal braces between horizontal beams or walls. The braces should be spaced according to seismic design requirements.
- For diagonal timber braces, ensure that the braces are securely attached to the top and bottom of the frame to resist lateral loads effectively.
- Timber braces should be designed with consideration for both axial and shear loads. Follow ANSI/APA PRG 320 for timber structural design and ensure that timber quality meets the necessary strength ratings.

Figure 23: Timber Bracing

Applications:

- Steel braces are commonly used for seismic bracing due to their high strength and durability. Depending on the building's layout and load distribution, they can be configured as X-braces, K-braces, or Chevron braces.
- Timber bracing is often used in wood-frame buildings, adobe and historical structures. Timber braces are effective for light to medium loads and are easier to install in certain building types.

c. Column Jacketing

Description: Strengthening existing columns with additional concrete, steel or composite materials.

Specifications:

- Minimum jacket thickness: 75 mm for concrete jacketing.
- Use epoxy-coated steel reinforcement.
- Ensure the compressive strength of the new material is at least 10% higher than the existing concrete.
- Follow IS 15988:2013 guidelines for retrofitting.

Applications: Critical for older buildings with weak columns

Figure 24: Column Jacketing of Existing Buildings

d. Beam-Column Joint Reinforcement

Description: Strengthening joints where beams and columns intersect.

Specifications:

- Use carbon fiber-reinforced polymer (CFRP) wrapping for enhanced ductility.
- Install steel plates with bolt anchorage.
- Comply with FEMA 356 guidelines.

Applications: Essential for buildings constructed before modern seismic codes.

Figure 25: Beam - Column Joint Reinforcement

e. Roof Bracing

Description: Strengthening the roof structure to prevent collapse during earthquakes.

Specifications

- Use steel bracing members with a minimum yield strength of 250 MPa.
- Timber members should be treated with a minimum cross-section of 100 mm x 50 mm.
- Connections must use galvanized bolts, and plates must comply with ASTM A-153.
- Install diagonal bracing in a cross-pattern for maximum stability.

Applications: Suitable for both pitched and flat roofs.

Figure 26: Roof Bracing

f. Grout Filling in Cracks

Description: Grouting injects grout into a wall's cavities, consisting of cement and water. The technique is applicable where the extent of the wall's crack does not exceed one centimeter. Knowledge of the internal structure of the wall and the percentage of gaps is an element of concern when choosing the most appropriate grout mix.

Prepare sample tests for various grout mixes depending on the nature of the work. It is recommended that the cement-based grout passes through sieve number 16 to remove any lumps.

Holes are then cleaned from loose material and dust and the edges are smoothed. The grout is filled in using pressure and passes through the gaps, filling the vacuum by squeezing the air out of the masonry gaps.

Grouting Minor and Medium Cracks (width 0.5 mm to 5.0mm)

- Remove the plaster near the crack, exposing the cracks in masonry wall. Make the shape of the crack in the V-shape by chiseling out.
- Fix grouting nipples in V-groove on the faces of the wall at spacing 150-200mm c/c.
- Clean the crack with compressed air through nipples to ensure that the fine and loose material inside the cracked masonry has been removed.
- Seal crack on both faces of the wall with cement mortar 1:3 and allow it to gain strength.
- Inject water, starting with the nipple, fixed at a higher level and moved down so that the dust inside the cracks is removed and the masonry is saturated with water.
- Make cement slurry with 1:1 (1-non shrink cement: 1-water) and start injecting from the lowermost nipple till slurry comes out from the next higher nipple and then move to the next higher nipple.
- After injecting grout through all nipples, re-plaster the surface.

Figure 27: Cracks Filled with Grout

Grouting Major Crack (Crack width more than 5.0mm)

- Remove plaster in the vicinity of the crack, exposing the cracked masonry. Make the shape of the crack in the V-shape by chiselling out.

- Clean the crack with compressed air to make a V-groove.
- Fix grouting nipples in V-groove on both wall sides at 150-200mm c/c spacing.
- Clean the crack with the compressed air through nipples to ensure that the fine and loose material inside the cracked masonry has been removed.
- Seal the crack on both faces of the wall with polyester putty or cement mortar and allow strength to be gained.
- Inject water starting with nipples fixed at a higher level and moving down so that dust inside the crack is removed & masonry is saturated with water.
- Make cement slurry with 1:2: water (1-non shrinking cement: 2 fine sands: just enough water) and start injecting from the lowermost nipple till the slurry comes out from the next higher nipple & then move to the next higher nipple.
- After injecting grout through all nipples, re-plaster the surface.

Figure 28: Grouting of Major Cracks in Walls and Columns

2 Retrofitting Against Flood Damages

a. Elevating the Structure

Description: Raising the building above the flood level using stilts or piers.

Specifications:

- Minimum elevation: 2 feet above Base Flood Elevation (BFE).

- Use reinforced concrete or treated timber for stilts.
- Ensure structural connections comply with FEMA P-550 standards.

Applications: Suitable for flood-prone lowlands.

Figure 29: Elevated Houses using Stilts

b. Dry Floodproofing

Description: Sealing the exterior walls of the building to make them watertight.

Specifications:

- Use waterproof membranes with a minimum tensile strength of 15 MPa.
- Install non-return valves in drainage outlets.
- Adhere to **ASCE 24-14** standards.

Applications: Applicable to commercial and residential buildings.

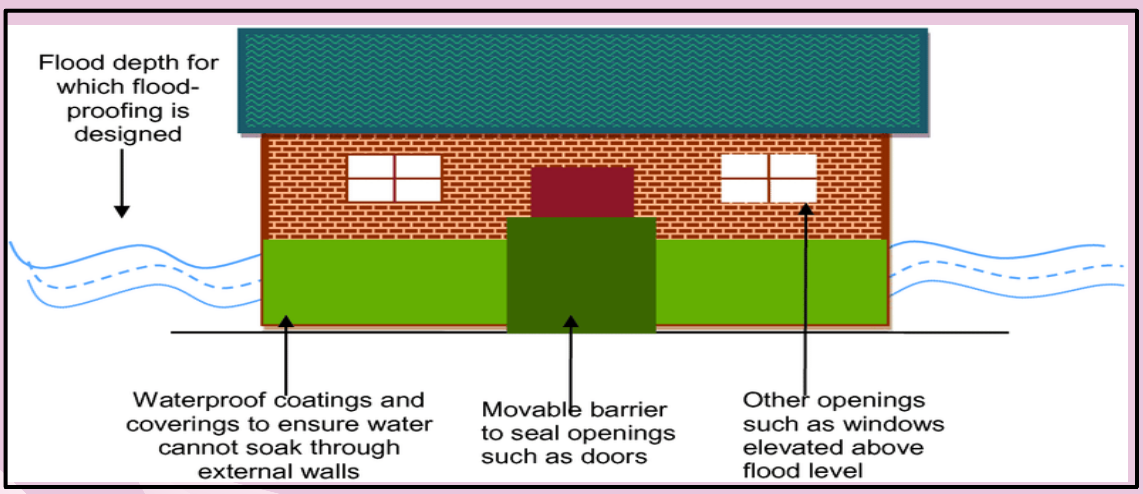

Figure 30: Dry Floodproofing of Exterior Walls

c. Wet Floodproofing

Description: Allowing water to enter specific building areas while minimizing damage.

Specifications:

- Use water-resistant materials such as concrete blocks or marine plywood.
- Ensure all electrical outlets are at least 1 meter above Base Flood Elevation.
- Install sump pumps with automatic float switches.
- Follow NFIP Technical Bulletin 7 guidelines.

Applications: Recommended for basements and garages

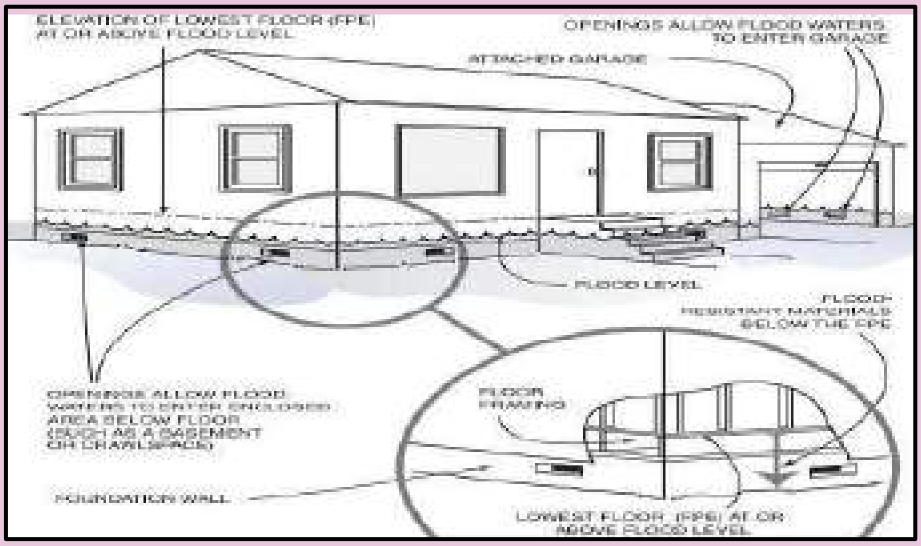

Figure 31: Wet Floodproofing of Houses

d. Foundation

Description: Strengthening the foundation to resist soil erosion and hydrostatic pressure.

Specifications:

- Embed foundations at least 1 meter below the scour depth.
- Use geotextiles with a tensile strength of 20 KN/m.
- Backfill with gravel to improve drainage.
- Adhere to **Eurocode 7** standards.

Applications: Necessary for houses near rivers or coastal areas.

Figure 32: Reinforcement of Foundation

e. Construction of Small Embankments

Description: Building low-height embankments around houses to deflect floodwaters.

Specifications:

- Minimum height: 1 meter above expected flood level.
- Use compacted earth or clay with a slope ratio 1:2 (vertical: horizontal).
- Reinforce with grass or geotextile to prevent erosion.
- Comply with local environmental regulations.

Applications: Effective for houses in rural and semi-urban flood-prone areas.

f. Installation of Sandbags Adjacent to Walls

Description: Flood-induced damages can be mitigated by strategically placing sandbags around the outer walls of buildings. Proper installation is crucial to ensure their effectiveness in minimizing water intrusion.

Specifications:

Sandbags: Use high-quality, durable polypropylene or burlap bags of approximately 18 inches x 30 inches (45 cm x 75 cm).

Sand: Coarse sand is recommended as it compacts easily and resists erosion.

Figure 33: Sandbags Installed Around the Perimeter of House

Placement Procedure:

- **Base Layer:** Lay the first row of sandbags directly adjacent to the outer wall of the building. Ensure that the open end of the bag faces away from the structure, so the filled part of the bag is towards the wall.
- **Orientation:** Place each sandbag flat and parallel to the previous one, ensuring they are well-packed. The bags should be placed end-to-end, not initially on top of one another.
- **Compact the Bags:** After filling each sandbag, compress it tightly to reduce air pockets. This helps the sandbags stay in place and increase their effectiveness.
- **Stacking:** Once the first layer is stable, add additional layers of sandbags. Stagger the seams of each successive layer, similar to brickwork, to prevent water from seeping through joints. Each layer should be slightly offset from the one below it.
- **Recommended height:** The stack height should be at least 3-4 feet (1 meter) for adequate protection, depending on the expected flood level.
- **Shaping:** Create a slope on the outer side of the sandbag wall, with the top of the stack sloping outward. This shape reduces water pressure against the wall.
- **Sealing Gaps:** Use additional materials, such as plastic sheeting or tarps, to cover any gaps in the sandbag walls, ensuring complete sealing from floodwaters.

- **Tying Bags:** If possible, tie the bags securely with twine to prevent them from shifting or falling apart under water pressure.

Application: Recommended for small buildings situated within plains.

General Recommendations

- Conduct a structural assessment before retrofitting.
- Hire certified professionals experienced in retrofitting.
- Use locally available materials to reduce costs.
- Integrate both seismic and flood-resistant measures in multi-hazard zones.
- Periodically inspect retrofitted components for wear and tear.

3 Retrofitting Guidelines for Hazards Resistant Learning Spaces

Usually, retrofitting is considered suitable if its cost is within 30% of the cost of new construction.

a. Retrofitting Intervention Stages:

- Firstly, the structural integrity is diagnosed using in-situ or laboratory testing for damage identification.
- Then, the design or redesign refers to an assessment of the current state based on measurable criteria set out by involved parties (education department, engineers, etc.), and it requires the architectural layouts, the building material properties, the modelling and analysis (based on local code and specifications framework), and the conclusion of preferred intervention methods.
- Accordingly, the decided method is implemented, ensuring the ability of masons to undertake retrofit works, the quality of materials and practical site inspection.

b. Hazard Damages & Retrofit Actions:

Table 4 provides structure wise suggested strengthening and retrofitting actions based on the nature and severity of damages for masonry buildings, RCC structures and adobes.

Table 4: Structure-wise Suggested Retrofitting and Strengthening Actions

Masonry Buildings			
Sr. No.	Damage	Nature of Damage	Suggested Action
1.	Negligible-slight damage (no structural, slight non-structural)	Fine cracks in plaster in walls at the base, in partitions and infill walls	Architectural repairs are needed.
2.	Moderate damage (Slight structural, moderate non-structural damage)	Cracks in columns and beams of frame and structural walls, in partition and infill walls, fall of brittle plaster and mortar from wall joints	Only architectural repairs are needed. Seismic strengthening is advised.
3.	Substantial heavy Damage (Moderate structural, heavy non- structural damage)	Cracks in column and beam at the base, splitting of concrete covers, buckling of steel bars, large cracks in partitions and infill walls	Wall cracks need grouting; columns need repair with architectural finish.
4.	Heavy damage (Heavy structural, very heavy non-structural damage)	Large cracks in structural elements with compression failure of concrete, bond failure of beam bars, tilting of columns, collapse of few columns or upper floor	Demolish and construct or extensive retrofitting with strengthening
5.	Destruction (Very heavy structural damage)	Collapse of the ground floor or parts of the building	Clear the site and reconstruct

RCC Frame Buildings			
Sr. No.	Damage	Nature of Damage	Suggested Action
1.	Negligible-slight damage (no structural, slight non-structural)	Fine cracks in plaster over frame members or in walls at the base, in partitions and infill	Only architectural repairs are needed. Seismic strengthening is advised.
2.	Moderate damage (Slight structural, moderate non-structural damage)	Cracks in columns & beams of frame, in structural walls, in partition and infill	Architectural repairs are needed. Seismic

		walls, fall of brittle plaster, falling mortar from joints of wall panel	strengthening advised
3.	Substantial heavy Damage (Moderate Structural, heavy non-structural damage)	Cracks in column and beam at the base, spalling of concrete covers, buckling of steel bars, large cracks in partitions and infill walls, failure of individual infill panels	Cracks in the wall need grouting, and columns need repair with architectural finish and seismic strengthening.
4.	Heavy damage (Heavy structural, very heavy non-structural damage)	Large cracks in structural elements & compression failure of concrete, bond failure of beam bars, tilting of columns, collapse of few columns or upper floor	Demolish and construct or extensive retrofitting and strengthening
5.	Destruction (Very heavy structural damage)	Collapse of the ground floor or parts of the building	Clear the site and reconstruction

Adobe Buildings			
Sr. No.	**Damage**	**Nature of Damage**	**Suggested Action**
1.	Negligible-slight damage (no structural, slight non-structural)	Fine cracks in cement/mud plaster in walls at the base, in partitions and infill	Architectural repairs are needed.
2.	Moderate damage (Slight structural, moderate non-structural damage)	Cracks in structural walls, in partition and infill walls, fall of brittle cement/ Mud plaster	Structural repair of walls needed. Wire meshing of walls recommended
3.	Substantial heavy Damage (Moderate Structural, heavy non-structural damage)	Large cracks in structural, partitions and infill walls, failure of individual infill	Structural repair of walls needed. Installation of wire mesh in

		panels, deflection in roof	walls and wooden bracing of the roof is recommended.
4.	Heavy damage (Heavy structural, very heavy non-structural damage)	Collapse of structural walls, large deflections in roof	Wooden bracing of the roof and construction of walls needed
5.	Destruction (Very heavy structural damage)	Collapse of roof	Clear the site and reconstruction

c. **Advantages of Retrofitting:**

- Retrofitting enhances the capacity of an existing structure scientifically to resist the forces of natural or man-made hazards or disasters, including earthquakes, flash floods, wind storms, blasts and fires which may occur. It undertakes remedial measures to remove the weaknesses identified in building construction. Its retrofitting provides the following advantages against rebuilding or reconstructing a building.
- The expense of demolition and debris removal, followed by reconstruction, is eliminated.
- The cost of retrofitting is generally no more than 10 to 20% of the construction cost of a new building. It is an economical option to reduce building vulnerability and provide safety to new occupants.
- Since the retrofit measures are applied only on small portions/ parts, the building finishes and functioning of facilities remain undisturbed. This saves the cost of redoing all that in a new building.

References

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- International Organization for Standardization (ISO): ISO 11600
- Federal Emergency Management Agency (FEMA): FEMA 356, FEMA P-550
- Eurocodes: EN 15129, Eurocode 7
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- Building Resilient Health Systems: a proposal for a resilience index doi: https://doi.org/10.1136/bmj.j2323
- Building Resilience Is critical in the face of increasing natural disasters https://www.resilienceindex.org/
- Building Resilience Index: User Guide https://documents.worldbank.org reports / document detail/099055006302240701 /p171993073a8 f00a90a 3bc0f47d5f87b

Annexure ‘A’

Standard References for Rating Checklist

Sr. No	Name	1	2	3	4	5
1.	Severity of Erosion of Soil for soil/foundation details	Severe and active soil erosion is visible around the foundation. Gullies, exposed roots, or cracks in soil are evident. No erosion control measures are in place.	Noticeable moderate erosion near foundation areas. Vegetation loss, minor soil displacement, and runoff signs are evident. Few or no mitigation measures in place.	Minor soil erosion or slope destabilization observed. Some vegetation present. Basic erosion control measures (like drainage or retaining structures) are in place but may be partially effective.	Well-managed soil with no significant signs of erosion. Dense ground cover or vegetation; effective slope stabilization (e.g., gabions, terracing).	Excellent erosion control: engineered solutions (retaining walls, riprap, advanced drainage), regular maintenance, stable soils with zero signs of degradation.
2.	Disturbance in Soil due to Animal Burrow	Multiple large, active burrows near or directly under the foundation. Visible soil collapse or hollowing. Droppings or fresh digging indicate ongoing animal activity.	One or more moderate burrows near structural periphery. Soil slightly loose. Minor cracks or sinking near entry points. Signs of intermittent activity.	Small or inactive burrows within 1–2 meters of the structure. No collapse or visible structural impact. Moderate vegetation cover.	No visible active burrows within structural zone (0–2 meters). Soil compacts and stable. Natural or manmade barriers (e.g., mesh, fencing) used to deter burrowing animals.	Well-maintained site with engineered animal control (e.g., deep foundation skirts, rodent barriers), dense ground cover, compacted fill. Wildlife management strategy actively enforced.
3.	Severity of Soil Retention by Structure	No soil retention structure present in areas with visible risk (e.g., slopes, cut/fill areas). Soil erosion, collapsing edges, or landslip evident. Cracks in nearby walls or tilting surfaces.	Weak or damaged retention system (e.g., cracked masonry wall, tilting gabion, eroded earth berm). Soil slumping or signs of stress (e.g., leaning fences or trees). Poor drainage behind structure.	Basic functional retention (e.g., stone wall, RR ties, timber) showing minor wear. Stable for now, but may lack weep holes or backfill drainage. No active failure but aged or under-designed.	Engineered soil retention using RCC, well-installed gabions, or geotextile-reinforced earth. Slope protection measures in place. Clear signs of stability and effective water management.	Advanced and well-maintained retention system with proper drainage (weep holes, backfill gravel), terracing, vegetation, and structural anchoring. No signs of movement, bulging, or erosion.
4.	Settlement Around the	Severe differential settlement visible: large	Moderate settlement (20–50 mm): visible	Minor settlement (5–20 mm): hairline cracks at	No visible settlement or cracks. Even perimeter	Engineered, reinforced foundation system with

	Perimeter of Building	cracks in foundation or walls, tilting of columns or steps, door/window misalignment, sunken ground > 50 mm. Often moist or spongy soil nearby.	minor cracks on walls or pavements, uneven floors, slight separation at joints. Soil near foundation slightly displaced or compacted.	corners, slight unevenness in paving or slab edges. Causes not progressing rapidly. Some moisture staining may be observed.	ground, stable steps/paths. Ground is dry, well-compacted, and free of slope toward foundation.	settlement control (e.g., piles, raft, or tie beams). Site shows professional grading, controlled drainage, and no signs of soil movement.
5.	Wall Conditions with Dampness/Seepage/Out of Alignment/Leaning in or out	Severe visible distress: wall visibly leaning (≥5°), out of plumb, large cracks (>5 mm), water seepage or damp patches extending upward from foundation. Salt (efflorescence) deposits and mold present.	Moderate misalignment or leaning (2–5°); diagonal cracks across openings; persistent dampness up to 1 meter high; flaking plaster or bubbling paint. Moisture control absent or failing.	Minor issues: small cracks (<2 mm), intermittent dampness during rains, slight out-of-plumb walls (≤2°). Paint discoloration or peeling near base. Drainage and moisture control present but possibly ineffective.	Walls plumb and dry. No visible cracks. Moisture barriers in place. Good ground slope and clear water runoff away from foundation. Ventilation adequate to prevent condensation.	Engineered and waterproofed wall systems (e.g., damp-proof course, cavity wall or RCC with waterproofing). No cracks, no dampness, no misalignment. Foundation and superstructure integrated.
6.	Severity of Cracks (Pattern and Nature)	Severe cracks: wide (>10 mm), deep, long, and extensive. Includes horizontal or stepped cracks in foundation walls, large diagonal cracks crossing structural elements, soil fissures, or large gaps exposing reinforcement.	Moderate cracks: widths between 5–10 mm; prominent vertical or diagonal cracks in walls or foundation; cracks extending through masonry or concrete; soil cracks near foundation edges	Minor cracks: hairline or narrow cracks (<5 mm) in foundation or soil surface; vertical or horizontal; limited length and no active widening. No visible displacement or water seepage.	Very fine cracks or no cracks: minor shrinkage or surface cracks in non-structural areas; no impact on load-bearing elements; no seepage or movement.	No visible cracks in foundation or soil; uniform surface; well-maintained joints; reinforced and engineered to prevent cracking.
7.	Vegetation/Tree Root Damage to Structure	Large trees with roots visibly breaking or lifting foundation slabs, causing large cracks (>10 mm), displaced pavements, or visible gaps near foundation edges. Dense root mats	Medium-sized roots causing minor cracking or surface displacement (5–10 mm). Roots visible near foundation but no major displacement yet. Signs of soil disturbance	Small roots or vegetation close but no visible structural damage. Minor soil disturbance or slight moisture retention near foundation. Vegetation controlled but not fully removed.	Vegetation planted with adequate setback from structure; no roots near foundation; ground stable with no cracks or displacement. Root barriers or landscaping measures in place.	No nearby trees or invasive vegetation within critical distance. Professional landscaping with engineered root barriers and soil stabilization. Soil compacts and stable.

		undermining soil stability.	or moisture accumulation.			
8.	Infiltration Condition in Building	Active water leaks or seepage inside walls, floors, or ceilings; visible mold, damp patches, peeling paint; water pooling inside building during or after rain.	Signs of intermittent moisture penetration: damp walls during heavy rains, minor water stains, slight mold growth, or musty odor.	Occasional minor damp spots with no active leaks; intact seals on windows/doors; some evidence of prior repairs.	Dry interiors with no visible dampness or leaks; well-maintained waterproofing membranes, gutters, and sealants; functional drainage away from building.	Advanced waterproofing systems: sealed building envelope, drainage integrated with foundation, use of vapor barriers, regular inspection and maintenance, zero infiltration signs.
9.	Algae/Fungi on the Surface of the Building	Heavy, widespread algae/fungi growth covering large surface areas (walls, roofs, foundations). Surfaces are discolored, slippery, or degrading visibly.	Moderate algae/fungi patches on shaded or moisture-prone areas, some surface discoloration and material softening.	Minor algae/fungi spots mostly localized to cracks, joints, or shaded corners. Surface generally intact	Very minimal algae/fungi presence, only after prolonged wet periods. Building surfaces mostly clean and dry.	No visible algae or fungi. Building surfaces dry, well-maintained, with effective drainage and ventilation.
10.	Drainage Capacity	Drainage system visibly inadequate or blocked: water pooling near foundation or on site, overflowing drains, muddy or eroded soil, no functional gutters or downspouts.	Drainage system partially functional but often overwhelmed: slow drainage, minor water accumulation, clogged or damaged components. Signs of erosion or soil saturation.	Drainage mostly functional; occasional water pooling during heavy rain, but no standing water after a short period. Gutters/downspouts in place but may lack capacity or full maintenance.	Effective drainage system with no water pooling, well-maintained gutters, downspouts, and surface grading directing runoff away from structure.	Advanced, engineered drainage: large capacity systems, stormwater retention/detention, permeable surfaces, regular maintenance, and monitoring. No water accumulation under any observed conditions.
11.	Flash Joints, Weep Holes, etc	Flash joints missing, blocked, or severely damaged. Weep holes absent or clogged. Signs of water buildup, seepage, or bulging walls behind structures.	Flash joints/weep holes present but partially blocked or poorly maintained. Minor signs of moisture accumulation or efflorescence near joints.	Flash joints and weep holes functional but some minor debris or partial blockage visible. No active water damage observed.	Flash joints and weep holes fully functional, clean, and unobstructed. Properly spaced and integrated into structure design. No signs of water buildup.	Engineered flashing and drainage systems with redundant weep holes, mesh guards, and maintenance plan. Continuous monitoring and immediate cleaning protocols in place.
12.	Severity of Chemical Corrosion	Severe corrosion visible: extensive rusting on exposed	Moderate corrosion: rust stains, surface cracking or spalling on concrete,	Minor corrosion signs: slight rust spots, surface efflorescence, minor	Very minimal or no corrosion: well-maintained materials with protective	No visible corrosion; materials treated or designed to resist chemical attack (e.g.,

		steel reinforcements, crumbling concrete with powdery or flaky surface, deep pitting, or chemical stains on soil/foundation.	localized pitting, discoloration of foundation materials.	concrete discoloration with no active degradation.	coatings intact, no rust or spalling visible.	corrosion-resistant steel, chemical barriers, sealants).
13.	Building Material Used	Poor-quality, non-engineered materials: unburnt bricks, mud, weak adobe, degraded timber, or reclaimed materials showing visible decay or brittleness.	Low-grade masonry (poorly fired bricks, hollow blocks), untreated timber, or mixed materials with signs of weathering or surface damage.	Standard masonry (burnt bricks, concrete blocks), treated timber, or lightweight precast panels with minor wear but generally sound.	High-quality engineered materials: reinforced concrete, stone masonry with good mortar, treated and fire-retardant timber, fiber-reinforced panels. Good condition.	Advanced materials and construction: seismic-resistant reinforced concrete, engineered stone veneer, fireproof cladding, corrosion-resistant finishes maintained regularly.
14.	Severity of Deflection, Cracks (Type, Width, Depth and Crack)	Severe deflection (>10 mm displacement), wide cracks (>10 mm), deep cracks exposing reinforcement, horizontal or stepped cracks, long and extensive damage.	Moderate deflection (5–10 mm), cracks 5–10 mm wide, diagonal or vertical, with some depth but not fully through the structure.	Minor deflection (<5 mm), hairline to narrow cracks (<5 mm), mostly surface-level, limited length, no exposure of reinforcement.	Very slight or no deflection, very fine cracks only (hairline shrinkage cracks), no structural concern.	No visible deflection or cracks. Wall/parapet is plumb and intact, well-maintained with engineered design.
15.	Severity of Surface Defects	Severe surface defects: large areas of spalling, deep scaling, widespread cracking, exposed aggregate, or severe erosion. Surface visibly deteriorated.	Moderate defects: noticeable spalling or scaling on limited areas, blistering paint, localized erosion, or minor surface cracking.	Minor surface defects: small chips, minor scaling, slight discoloration, or isolated spots of wear without significant depth.	Very minimal defects: slight surface wear consistent with age, no active deterioration. Surfaces mostly intact and protective coatings effective.	No visible surface defects. Surfaces smooth, intact, and well-protected with quality coatings or finishes.
16.	Damages to Parapets and Chajjas	Severe damage: large cracks, partial or complete detachment, exposed reinforcement, crumbling edges, missing sections, or loose materials.	Moderate damage: visible cracks, chipped or spalled concrete, minor detachment or looseness, rust stains on reinforcement.	Minor damage: small cracks, slight spalling, surface wear without loose parts or structural compromise.	Very minor or no damage: only superficial wear or paint peeling; parapets and chajjas structurally sound.	No visible damage; parapets and chajjas well-maintained, structurally robust, and properly anchored.

17.	Signs of Water Filtration Around Openings and Other Parts	Active water infiltration: visible wet patches, mold, efflorescence, peeling paint, or water stains around openings. Water pooling inside or structural swelling.	Signs of intermittent moisture penetration: dampness, minor staining, or mold growth during/after rain.	Minor signs of past water penetration, such as faint stains or slight discoloration; no active leakage.	No visible signs of infiltration; seals and flashing intact and well-maintained.	Advanced waterproofing measures in place: sealed openings with durable membranes, flashings, and drainage provisions; no signs of moisture ingress.
18.	Severity of Cracks in the Joining of Masonry	Large, wide cracks (>10 mm) in mortar joints; crumbling or missing mortar; visible gaps leading to loose masonry units.	Moderate cracks (5–10 mm) with some mortar degradation; small gaps forming but masonry mostly intact.	Minor cracks (<5 mm), mostly hairline; mortar intact with no loose units.	Very fine or no cracks; mortar joints sound, no signs of deterioration.	No visible cracks; high-quality mortar used; joints well-maintained and protected from weathering.
19.	Deflection and Sagging of Wall Above or Below the Openings	Severe sagging or visible deflection (>10 mm), cracks radiating from openings, deformation of lintels or sills, noticeable displacement.	Moderate sagging/deflection (5–10 mm), minor cracking around openings, slight deformation of structural elements.	Minor sagging or deflection (<5 mm), small hairline cracks, no visible deformation of lintels or sills.	Very slight or no sagging/deflection, no cracking; structural elements above/below openings intact.	No deflection or sagging; openings well-supported with engineered lintels and sills, no visible damage.
20.	Diagonal Cracks at the Corner of Openings	Wide diagonal cracks (>10 mm), extending from corners, with signs of displacement or separation of masonry units.	Moderate diagonal cracks (5–10 mm) at corners, with minor displacement or mortar deterioration.	Minor diagonal cracks (<5 mm), mostly hairline, no displacement or loose units.	Very fine or no diagonal cracks; corners intact with no visible distress.	No cracks; reinforced openings with adequate lintels/frames preventing stress concentration.
21.	Distortion of Openings	Significant distortion: visibly warped, twisted, or misaligned frames; difficulty in opening/closing; gaps causing water or air infiltration.	Moderate distortion: slight misalignment or warping; minor operational issues; some gaps around frames.	Minor distortion: slight irregularities without operational impact or gaps.	Very slight or no distortion; openings fit well and operate smoothly.	No distortion; precision-engineered openings with reinforced frames maintaining shape under all conditions.
22.	Water Infiltration symptoms	Active water leakage visible: wet patches, dripping, pooling water,	Signs of frequent moisture exposure: dampness, staining,	Past moisture signs: faint stains or discoloration	No visible signs of moisture infiltration; seals and	Advanced waterproofing: durable membranes, properly installed flashing, and regular

		mold growth, efflorescence, peeling paint, or damaged finishes around openings.	minor mold spots, or efflorescence during/after rain.	without active leakage or mold.	flashings intact and effective.	inspections showing no moisture issues.
23.	Evidence of Abrasion and Impact	Severe abrasion or impact damage: large chips, deep scratches, cracks, broken frames, or crushed areas compromising structural integrity.	Moderate damage: noticeable surface wear, multiple scratches, minor cracks or dents, some loose parts.	Minor abrasions or shallow scratches; no cracks or loose components.	Very slight surface wear with no structural concern or material loss.	No visible abrasion or impact damage; surfaces smooth and well-maintained.
24.	Evidence of Termite Effects on Doors and Windows	Severe termite damage: hollowed wood, visible tunnels, crumbling sections, loose or falling parts, active termite presence.	Moderate damage: visible surface damage, small tunnels or galleries, weakened joints, signs of past infestation.	Minor damage: slight surface damage or small holes without structural compromise.	Very minimal signs: occasional minor blemishes or no active infestation signs.	No signs of termite damage; wood treated and regularly inspected.
25.	Condition of Material Used for Doors, Windows, etc.	Poor-quality or severely deteriorated materials: rotted wood, rusted metal, cracked or warped frames, broken glass, or brittle plastics.	Low-grade materials with visible wear: surface corrosion, minor rot, peeling paint, loose fittings.	Standard materials in fair condition: minor wear, no major defects or structural issues.	High-quality materials with minor aging signs: treated wood, galvanized metals, intact finishes.	Premium, engineered materials: treated hardwoods, stainless steel/aluminum frames, impact-resistant glass, well-maintained.
26.	Water Proofing	Extensive waterproofing failure: visible ponding, leaks, blistering or peeling membranes, cracks in waterproof layer, active water ingress.	Partial waterproofing defects: localized cracks or blisters, minor leaks, early signs of membrane deterioration.	Generally intact waterproofing with minor wear or superficial defects, no active leaks.	Well-maintained waterproofing: no visible damage, effective drainage, intact membranes.	Advanced waterproofing systems: multi-layer membranes, regular maintenance, and inspections, proactive repairs.
27.	Water Stagnancy	Extensive stagnant water pools visible after rainfall, lasting more than 48 hours, with	Noticeable water pooling in several areas lasting 24-48 hours; minor algae or surface degradation.	Occasional water pooling lasting less than 24 hours; minimal impact on surface condition.	No persistent water stagnancy; water drains quickly and roof surface remains dry.	Designed slope and drainage prevent any water pooling; roof surface remains dry even after heavy rain.

		algae/moss growth or material softening.				
28.	Condition of Roof Slopes, Rain Water Pipe, Clogging, etc.	Poor slope causing water ponding; severely clogged or broken rainwater pipes; visible overflow or leaks.	Inadequate slope with occasional ponding; partially clogged pipes; minor leakage or overflow.	Adequate slope with occasional minor ponding; mostly clear pipes with minor debris.	Properly sloped roof; clear rainwater pipes; no clogging; efficient water flow.	Optimized slopes and drainage systems; rainwater pipes well-maintained with debris screens; no clogging or overflow observed.
29.	Sagging of Roof	Severe sagging with visible deformation, cracks in supporting members, or water pooling due to uneven surface.	Moderate sagging noticeable to the eye; minor cracking or deflection of support elements.	Slight sagging detectable but no cracking or deformation; roof remains functional.	No visible sagging; roof surface even and support structure sound.	No sagging; roof designed and maintained with reinforced supports to prevent deflection under loads.
30.	Water Infiltration at Openings or joints, etc.	Active, severe leaks visible at openings or joints; water stains, mold growth, damaged flashing, or pooling water inside.	Noticeable leaks or seepage during rain; damaged or deteriorated flashing; minor water stains present.	Minor seepage or past signs of infiltration; no active leaks; flashing mostly intact.	No visible signs of leakage; joints and openings properly sealed and intact.	High-quality flashing and sealants installed; joints well-maintained; no infiltration under any conditions.
31.	Structural Defects on the roof surface	Severe defects: large cracks, spalling, holes, broken decking, exposed reinforcement, or significant deformation.	Moderate defects: multiple small cracks, minor spalling, surface degradation, but no major deformation.	Minor surface defects: hairline cracks, slight surface wear without affecting structural integrity.	Very minor or no visible defects; roof surface intact and sound.	No defects; roof surface reinforced and maintained to high standards.
32.	Cracks in the foundation Wall	Severe cracks (>10 mm width), horizontal or stepped, with displacement, water seepage, or loose masonry/concrete pieces.	Moderate cracks (5–10 mm), mostly vertical or diagonal, minor displacement, no loose pieces but potential water infiltration.	Hairline or fine cracks (<5 mm), no displacement, no water seepage.	Very fine or no visible cracks; foundation wall intact and sound.	No cracks; foundation walls well-constructed with reinforced concrete or masonry, regularly maintained.
33.	Location of Cracks	Cracks located near key load-bearing points (corners, beam supports), water table	Cracks near foundation-wall joints, window/door openings, or near	Cracks in non-critical areas such as surface plaster or outer walls, with minor	No cracks near critical zones; any cracks are hairline and located in non-load areas.	No cracks anywhere on foundation walls, especially near critical points.

		zones, or beneath heavy loads, especially if wide or deep.	drainage points with moderate width.	width and no signs of movement.		
34.	Differential settlement of Foundation	Severe differential settlement: visibly uneven foundation or floor levels, large cracks, tilting walls or columns, and significant structural distortion.	Moderate differential settlement: minor unevenness in floors or foundation lines, moderate cracks, some distortion of structural elements.	Slight differential settlement: minor unevenness without major cracks or distortion, mostly cosmetic signs.	Minimal differential settlement: foundation appears level with very minor signs of movement.	No differential settlement; foundation level and uniform throughout.
35.	Differential Settlement on Floor	Severe unevenness with visible dips or raised areas, cracks in floor finishes or slabs, noticeable trip hazards.	Moderate unevenness with minor cracks or surface irregularities causing discomfort but no structural failure.	Slight unevenness detectable by feel or level but no visible cracks or hazards.	Floor mostly level with very minimal differential settlement or surface wear.	Completely level floor with no signs of settlement or surface defects.
36.	Cracks on Floor	Severe, wide (>10 mm) cracks with displacement, spalling, or exposed reinforcement.	Moderate cracks (5–10 mm), no major displacement but visible.	Hairline or minor cracks (<5 mm), no displacement or structural concern.	Very minor or superficial cracks with no impact on structural integrity.	No cracks; floor surface intact and sound.
37.	Sagging/Bulging/Discoloring	Severe sagging or bulging with cracks, peeling, or water stains; areas visibly deformed or softened.	Moderate sagging or discoloring; localized bulging or staining without collapse but material weakening evident.	Slight discoloration or minor surface unevenness without structural deformation.	Minimal or no discoloration/sagging; surfaces largely even and intact.	No visible sagging, bulging, or discoloration; materials sound and well-maintained.
38.	Condition of Flooring	Severely damaged flooring: broken tiles, warped wood, loose or missing sections, water damage, or mold growth.	Damaged but partially functional flooring: cracked tiles, minor warping, surface wear, or slight moisture effects.	Flooring with moderate wear: small chips, scratches, or minor surface defects but structurally sound.	Flooring in good condition: intact surface, minimal wear, well-maintained.	Flooring in excellent condition: new or recently maintained, no defects, resistant materials.
39.	Partition Material and	Partitions made of weak, degraded, or combustible materials;	Partitions of moderate durability but showing damage or wear, minor	Partitions of standard durable materials (e.g., gypsum board, concrete	Well-maintained partitions made from fire-resistant,	Partitions constructed from high-performance, fire-

	Condition Detail	visible damage like cracks, holes, or severe warping.	cracks or moisture effects.	block), minor cosmetic defects only.	sturdy materials, no visible damage.	resistant, impact-resistant materials; excellent condition.
40.	Ceiling Material and Condition Detail	Ceiling made of weak or degraded materials (e.g., damaged plaster, corroded metal frames), with cracks, stains, or sagging.	Ceiling of moderate durability with minor damage or discoloration, slight sagging, or water stains.	Ceiling constructed from standard materials (e.g., gypsum, fiberboard) with minor cosmetic defects only.	Well-maintained ceiling made from fire-resistant or durable materials, no visible damage.	Ceiling built with high-performance fire-resistant, water-resistant, or impact-resistant materials; excellent condition.
41.	Sign of Water Penetration	Severe water stains, peeling paint/plaster, mold growth, damp patches covering large areas.	Noticeable water stains or damp patches, minor peeling, localized mold spots.	Minor discoloration or occasional damp spots with no visible mold or material deterioration.	No visible water stains or dampness; walls dry and intact.	Walls treated with water-resistant coatings/materials; no signs of water penetration under any conditions.
42.	Role of Wall (Structural Support/Masonry Infill)	Structural walls severely damaged, cracked, or compromised; infill walls failing or absent where critical.	Structural walls with moderate damage or deterioration; infill walls showing cracks or damage.	Structural walls intact with minor cosmetic defects; infill walls sound but non-structural.	Well-maintained structural walls and sound masonry infill with no significant defects.	Robust structural walls built to code with high-quality masonry infill; excellent maintenance.
43.	Plumb detail of Wall	Wall significantly out of plumb (>25 mm deviation over height), visible leaning or bulging.	Moderate plumb deviation (10–25 mm), slight leaning or bowing visible.	Minor plumb deviation (<10 mm), no visible leaning or bulging.	Walls well-aligned and plumb with negligible deviation.	Perfectly plumb walls with strict adherence to construction standards.
44.	Surface Defects of Wall	Severe surface defects: widespread peeling, spalling, large cracks, and exposed reinforcement.	Moderate defects: visible cracking, peeling paint/plaster, localized spalling.	Minor surface defects: small cracks or chips, minor peeling with no structural impact.	Very minimal or no surface defects; wall surface mostly intact and sound.	No surface defects; walls well-finished and maintained.
45.	Proper Alignment of Columns	Columns visibly misaligned with significant deviation from vertical (>25 mm), causing structural distortions.	Moderate misalignment (10–25 mm deviation), slight visible lean or tilt.	Minor misalignment (<10 mm), no visible lean but measurable deviation.	Columns well-aligned and vertical with negligible deviation.	Columns perfectly aligned per design specifications and standards.

46.	Plumb of Column	Column significantly out of plumb (>25 mm deviation), visibly leaning or bowed.	Moderate plumb deviation (10–25 mm), slight visible tilt or bowing.	Minor deviation (<10 mm), no visible lean or bowing.	Column well-aligned and plumb with negligible deviation.	Perfectly plumb columns adhering to design and construction standards.
47.	Cracks (In Column) Patterns of cracks Width/Depth of Cracks	Severe cracks: wide (>10 mm), deep, possibly exposing reinforcement, with complex patterns (e.g., diagonal, vertical, stepped).	Moderate cracks: 5–10 mm wide, moderately deep, noticeable but no exposed reinforcement.	Minor cracks: hairline to <5 mm wide, shallow, mostly vertical or horizontal.	Very fine surface cracks or no cracks visible.	No cracks; column surface intact and sound.
48.	Deflection	Severe deflection with visible sagging or deformation beyond permissible limits; possible cracking.	Moderate deflection noticeable but within safety margins; some minor cracking may be present.	Slight deflection within acceptable limits; no visible damage.	Negligible deflection; beams/girders appear straight and sound.	No deflection; structurally robust with no visible deformation.
49.	Cracking	Severe, wide (>10 mm), deep cracks, possibly exposing reinforcement; extensive cracking patterns (diagonal, horizontal, vertical).	Moderate cracks (5–10 mm), noticeable but no exposed reinforcement; some localized distress.	Minor cracks (<5 mm), mostly hairline or surface level, no structural compromise.	Very fine or no cracks visible; sound structural condition.	No cracks; beam/girder surfaces intact and undamaged.
50.	Change in Section sizes	Sudden, unreinforced or poorly detailed changes in section size; noticeable weak points or abrupt transitions.	Changes in section size with partial reinforcement or minor detailing issues.	Gradual, well-reinforced section changes as per design with minor cosmetic defects.	Smooth, well-executed section transitions with appropriate reinforcement and no defects.	Perfectly designed and detailed section changes adhering to all codes and best practices.
51.	Corrosion Condition	Severe corrosion with extensive rust, spalling concrete, exposed and heavily corroded reinforcement.	Moderate corrosion with visible rust patches, minor spalling or cracking around corroded areas.	Minor corrosion signs like surface rust or small patches with no spalling.	Negligible corrosion; sound surface with protective coatings intact.	No visible corrosion; excellent condition with effective corrosion protection measures in place.
52.	Condition of Lateral Support of	Lateral supports missing, severely damaged, or ineffective; framing unstable.	Lateral supports present but damaged, loose, or partially compromised.	Lateral supports present and functional but showing minor wear or defects.	Well-maintained, intact lateral supports providing effective stabilization.	Excellent lateral support system, designed and maintained per best standards.

	Framing Structures					
53.	Evidence of Abrasion	Severe abrasion with exposed reinforcement, significant material loss, rough or pitted surfaces.	Moderate abrasion causing surface roughness, minor material loss, but no exposed reinforcement.	Minor abrasion with slight surface wear, no material loss or structural effect.	Minimal or no abrasion; surfaces intact and well-protected.	No abrasion; surfaces pristine and effectively maintained.
54.	Abrasion due to Sliding or Cracks Due to Stress Concentration	Severe abrasion and deep cracks at stress points; visible material loss and deformation.	Moderate abrasion with noticeable cracks concentrated near joints or supports.	Minor abrasion and hairline cracks in stress areas with no structural compromise.	Minimal abrasion and no visible cracks at stress concentration points.	No abrasion or cracks; stress points well-protected and intact.
55.	Severity of Cracks/Deflection (Location)	Severe cracks or deflection at critical points (supports, joints, mid-span) with wide/open cracks or excessive sagging.	Moderate cracks or deflection at critical locations with noticeable deformation or crack width.	Minor cracks/deflection at non-critical locations or minor cracks at critical spots.	Very minor cracks or deflection, not affecting load-bearing or connection areas.	No cracks or deflection anywhere, especially at critical points.
56.	Severity of Cracks/Deflection at the Intersection of Beams and Columns, Beams and Slabs, Columns and Foundations	Severe, wide (>10 mm), deep cracks or significant deflection/deformation; possible spalling or exposed reinforcement	Moderate cracks (5–10 mm) or noticeable deflection with minor spalling or damage.	Minor cracks (<5 mm), hairline or shallow, slight deflection not affecting load transfer.	Very fine or no cracks; no visible deflection or damage; sound connections	No cracks or deflection; robust, well-maintained intersections per design.
57.	Condition of Steel/Other Connections	Severe corrosion, rust, loosening, missing bolts, cracked welds, or broken plates.	Moderate corrosion, some loosening, minor cracking or deformation of connection components.	Minor surface rust or wear, connections intact and functional.	Well-maintained, clean, and tight connections with no signs of distress.	Excellent condition, properly installed and inspected connections per standards.
58.	Severity of Surface Defects at	Severe surface defects: deep spalling, large	Moderate defects: moderate cracks, minor spalling, surface rust.	Minor surface cracks or slight discoloration; no spalling or exposure.	Minimal surface defects; clean and intact surfaces.	No surface defects; pristine condition at connections.

	Connections or Intersecting Areas	cracks, rust flakes, exposed reinforcement.				
59.	Corrosion Severity of Steel-to-Steel Connections	Severe corrosion: heavy rust buildup, pitting, flaking, and significant section loss.	Moderate corrosion: visible rust, minor pitting, some surface loss.	Minor surface rust or discoloration without pitting or section loss.	Negligible corrosion; clean surfaces with protective coatings intact.	No corrosion; steel-to-steel connections fully intact and well-protected.
60.	Cracking at Column Base	Severe, wide (>10 mm), radial or shear cracks radiating from column base; signs of spalling or sinking.	Moderate cracks (5–10 mm) around base, with slight spalling or pattern consistent with stress concentration.	Minor cracks (<5 mm), hairline or shrinkage type, with no apparent deformation.	No visible cracks; clean junctions with sound transition from column to slab.	No cracks; design includes proper reinforcement for punching shear, and condition is excellent.
61.	Severity of Settlements	Severe settlement (>50 mm); visible sagging, cracking, slope formation, or separation from walls/columns	Moderate settlement (20–50 mm); visible level change, cracking, or localized depressions.	Minor settlement (5–20 mm); no structural cracking, but slight unevenness present.	Negligible settlement (<5 mm); floor mostly level and sound.	No visible or measurable settlement; perfectly level with firm support.
62.	Floor/Wall Settlements/Separations or Settlements	Significant separation (>25 mm) between floor and wall; visible gaps, cracks, or daylight passing through; structural movement evident	Moderate separation (10–25 mm); visible cracking or slight wall rotation near floor junctions.	Minor separation (5–10 mm); small visible gaps or cracks, no structural movement evident.	Very small gaps (<5 mm); largely cosmetic with no signs of structural stress.	No visible separation; flush and tight floor-to-wall junctions.
63.	Condition of Water Proofing	Waterproofing fully failed: extensive leakage, blistering, exposed or torn membrane, visible deterioration.	Major damage or wear: patchy or ineffective waterproofing, localized leaks or water stains visible.	Minor cracks or wear in waterproofing layer, but no current leakage.	Waterproofing in good condition; no leaks or visible damage; well-applied and adhered.	Excellent waterproofing; recently installed or well-maintained system with full coverage and drainage compatibility.
64.	Circumferential Cracking Severity (if any)	Wide (>10 mm), deep, continuous circumferential cracks around structural elements; signs of	Moderate cracks (5–10 mm), partial circumference affected, may show signs of widening or propagation.	Minor cracks (<5 mm), shallow or partial, no visible damage beyond cracking.	Very faint circumferential cracking or cosmetic surface marks only.	No circumferential cracks present.

		distress, spalling, or water ingress.				
65.	Severity of Cracks	Wide (>10 mm), deep cracks with separation or dislocation of tiles/concrete; may form a pattern or run across large areas.	Moderate cracks (5–10 mm), isolated or spreading; minor lifting or misalignment of floor materials.	Minor cracks (<5 mm), hairline or superficial; no impact on flooring function.	Very faint surface marks; only visible under close inspection, no spread.	No cracks; flooring fully intact and level.
66.	Severity of Settlements	Severe settlement (>50 mm); large depressions, slope formation, detachment from skirting/walls, possible cracks or tilting.	Moderate settlement (20–50 mm); uneven surfaces with visible dips or cracking.	Minor settlement (5–20 mm); localized unevenness, no cracking but slight deflection felt.	Negligible settlement (<5 mm); even surface with no defects.	Absolutely level floor with no signs of settlement or movement.
67.	Floor/Wall Settlements/Separations or Settlements	Major separations (>25 mm), cracking along junctions, detachment of floor finishes from walls, or visible daylight through gaps.	Moderate separation (10–25 mm), continuous cracking or visible level mismatch between wall and floor	Minor separation (5–10 mm), local cracks or visible joint lines with slight movement.	Very slight separation (<5 mm), hairline cracks only at junctions.	Very slight separation (<5 mm), hairline cracks only at junctions.
68.	Severity of Circumferential Cracking	Wide (>10 mm), deep circumferential cracks forming a continuous ring; possible spalling or water ingress.	Moderate cracks (5–10 mm), mostly continuous but limited spalling or surface deterioration.	Minor cracks (<5 mm), partial ring formation, no spalling or severe defects.	Very faint or hairline circumferential cracks, mostly cosmetic.	No circumferential cracks detected.
69.	Damages on Stairs	Severe damages: broken or missing steps, large cracks, spalling, unstable treads or risers, loose handrails.	Moderate damages: significant cracks or chips, some loose components but still functional with caution.	Minor damages: small chips, hairline cracks, slightly worn surfaces; fully functional.	Very minor surface wear; no structural damage or safety hazards.	No visible damages; structurally sound and safe.
70.	Cracking/Corrosion	Severe cracking (wide, deep) with exposed and heavily corroded reinforcement; spalling concrete.	Moderate cracks with visible corrosion patches; minor spalling or rust staining.	Hairline cracks with slight surface corrosion, no spalling or exposed reinforcement.	Minimal cracking with negligible corrosion, no exposure of reinforcement.	No cracks or corrosion detected; excellent condition.

71.	Exposure of Reinforcement (if any)	Extensive reinforcement exposure with heavy corrosion, spalling concrete, and visible structural distress.	Moderate areas of exposed steel with visible rust; minor spalling present	Small patches of exposed reinforcement with minor surface rust; no spalling.	Minimal or no visible reinforcement exposure; well-covered by concrete.	No reinforcement exposure; fully intact concrete cover.
72.	Condition of Hand Rails, Rise, Treads, Landing, Platform, etc.	Handrails missing or severely damaged; uneven or broken treads; unstable landings/platforms; trip hazards.	Handrails loose or partially damaged; noticeable wear or cracks on treads; minor instability in landings.	Handrails intact but showing signs of wear; treads and landings stable with minor surface defects.	Good condition handrails, even rise and treads; landings/platforms stable with no defects.	Excellent condition; robust handrails, uniform rise, no defects in treads or platforms.
73.	Condition of Connection/Anchorage of Hand Rails	Handrails loosely attached or detached; corroded or broken anchors; unstable or missing fasteners.	Weak or partially damaged connections; signs of corrosion or looseness; reduced load capacity.	Connections intact but showing minor wear or surface corrosion; securely fastened.	Good condition connections; well-fastened and corrosion-free anchors.	Excellent condition; robust anchorage with no signs of wear or looseness.
74.	Condition of Chord, Grills, Doors, Buttons, Switches, Fan, Lights, etc.	Non-functional or severely damaged components; exposed wiring; broken switches; inoperable fans or lights.	Intermittent operation; some components malfunctioning or showing damage; minor electrical hazards.	Components functional but showing wear or minor defects; all safety features intact.	All components working well; minimal signs of wear or aging.	New or recently serviced components; fully operational and tested.
75.	Severity of Leakages/Seepages Due to Pipes/Fittings Etc.	Major active leaks causing visible water pooling, structural dampness, mold, or corrosion; continuous seepage.	Moderate leaks or seepages causing damp patches, minor pooling, or visible water stains.	Minor leaks with occasional dampness, no pooling or mold growth yet.	No active leaks; occasional minor moisture spots with no damage.	No signs of leakage or seepage; dry and intact plumbing and fittings.
76.	Condition of All the Pipes with Fittings and Accessories	Pipes and fittings heavily corroded, cracked, leaking, or broken; multiple accessory failures.	Noticeable wear, minor leaks, surface corrosion, or loose fittings; some accessories malfunctioning.	Minor surface wear or aging; all fittings and accessories functional with no leaks.	Pipes and fittings in good condition; minimal signs of aging or corrosion; accessories fully functional.	New or recently replaced pipes, fittings, and accessories; excellent condition and performance.

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